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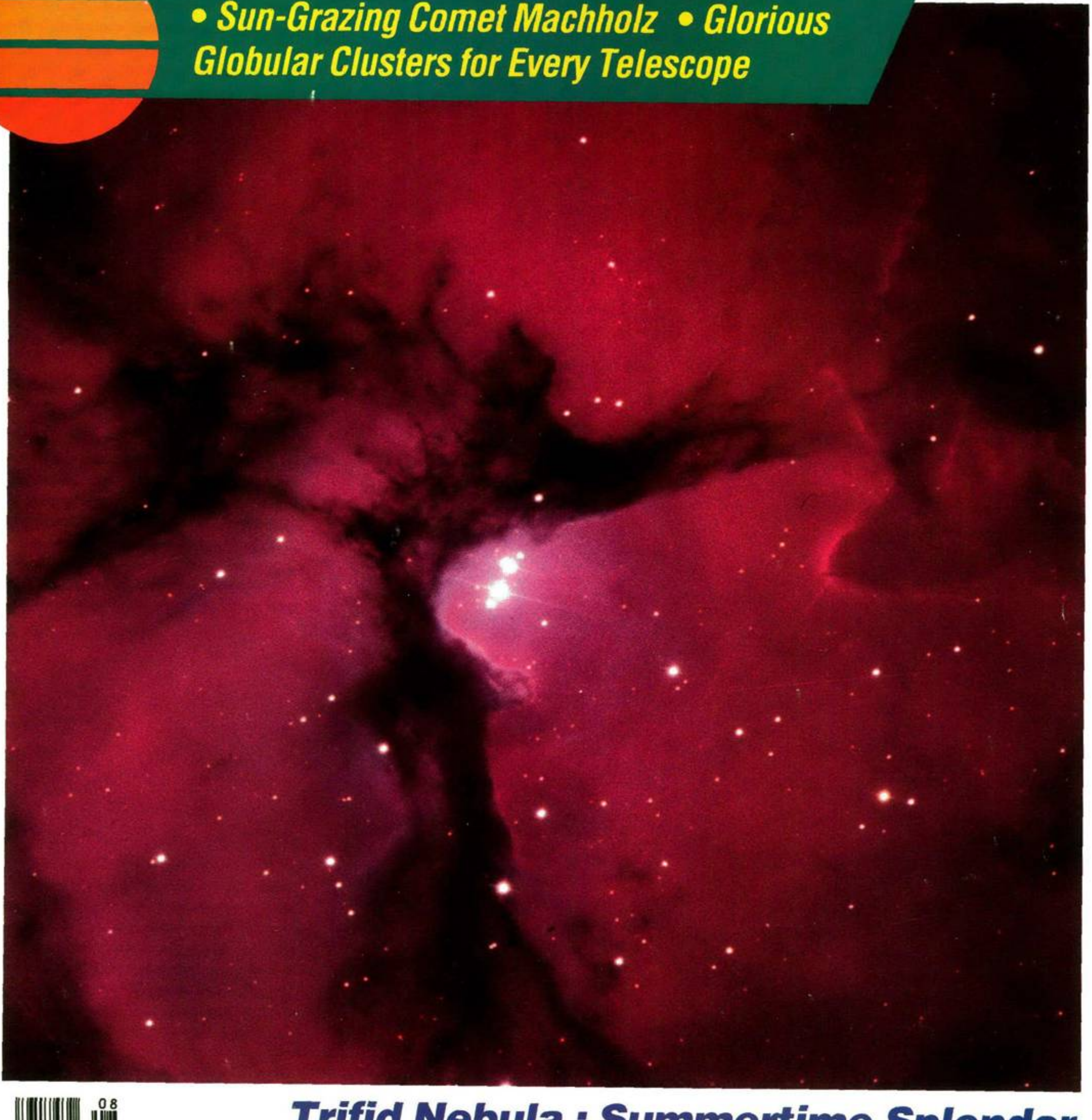

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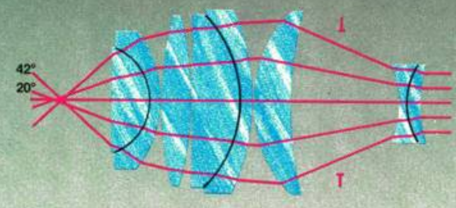

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—**Roland Christen,** President, Astro-Physics Corp., Rockford, IL

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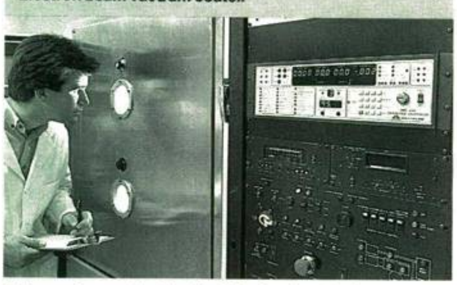

"I have been absolutely delighted with the superior performance of the Meade 10″ Schmidt-Cassegrain. The optics are superb. At a recent star party Omega Centauri was resolved into thousands of tiny pinpoints into its core...Many said they were thrilled not only to see so much spiral structure in the Whirlpool Galaxy (M51) but also to see the faint bridge between the two components of M51."
—**L. J. Alfonso,** Boca Raton, FL

Primary Mirror Central Coring: Before Meade 4″, 8″ and 10″ SC primary mirrors can be polished and figured to within exacting optical tolerances, the central perforation, or

al Performance..."Superior...Superb...Breathtaking."

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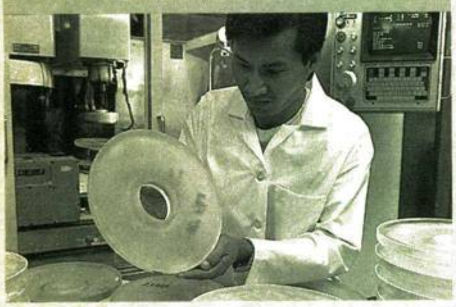
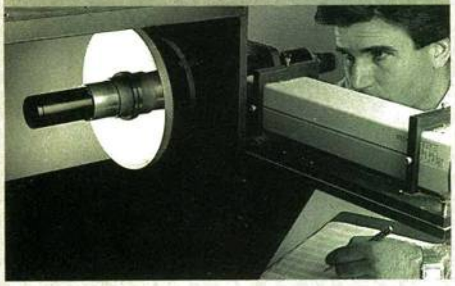
CNC coring of SC primary mirrors.



"When unpacking my Meade 10" SCT I realized that the amount of work which had gone into making this instrument was incredible...every detail was perfect down to the last nut and bolt. On the first clear night I took the scope out to check the optics. Quite simply the views were breathtaking! Star images matched textbook versions letter for letter, showing perfect symmetry in and out of focus."
—J. Spang, Chorely, England.

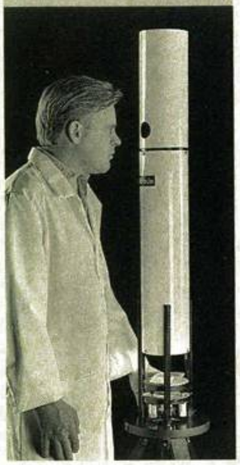
Optical Testing: As each Meade 3-element SC optical set (primary mirror, secondary mirror, and correcting plate) progresses through the grinding, polishing, and final hand-matching stages of development, it is continuously tested and re-tested for zonal irregularities, smoothness, and correction. Intermediate testing is performed using the Foucault and Ronchi methods; final diffraction image testing is done with a double-pass laser autocollimator that passes an intense pinhole of monochromatic light through the 3-element system *twice*, enabling the technician to detect errors (at an effective magnification of 1000X) beyond the observable limit of the field user. If we seem unusually confident in the capabilities of Meade Schmidt-Cassegrain optics, it is because we know that every optical set is put through this battery of over 30 separate optical tests and inspections before the optics are mounted in the optical tube and shipped to you.

Autocollimator testing of an 8" SC system.



"Using my Meade 8" SCT under just fair seeing the 1.0 arc sec double Zeta Boötes was beautifully separated, with plenty of dark space between the circular Airy discs. At lower power the four stars of Epsilon Lyrae were also cleanly separated and a beautiful sight, with all in the same field."
—R. Knight, Stow, OH

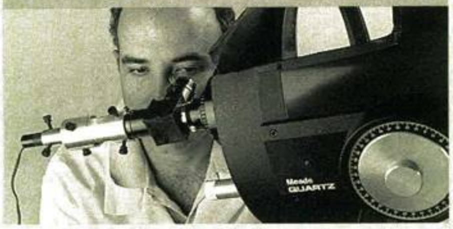
Interferometric testing of diagonal flats.



Diagonal Flat Testing: Integral to the functioning of any high-performance Cassegrain system is the optical smoothness and flatness of the diagonal surface. Every Meade diagonal mirror is tested for flatness on a Fizeau laser interferometer; mirrors which pass this test are coated with enhanced aluminum and mounted in their machined diagonal housings.

Optical Alignment: Finished, individually matched 4", 8" and 10" SC optical sets are sent to the optical alignment department, where each set is placed into a special cut-out optical tube that permits rotation of the optical elements about the optical axis. (The relative rotational orientations of the Schmidt-Cassegrain primary mirror, secondary mirror, and correcting plate are *not* arbitrary.) Rotation of the optics, while the technician observes an artificial starpoint under controlled laboratory conditions at high power, yields the unique relative orientation that cancels out any residual aberrations of the system. With optimal orientation thus fixed, each optics set is placed into the machined housings of its optical tube. The optical system is once again tested for roundness, regularity, and consistency of the diffraction image inside and outside of focus. Only after passing this final test is an optical tube system ready to become part of a Meade Schmidt-Cassegrain telescope.

Rotational orienting of 10" SC optics.



"As a former staff member at Mt. Wilson and Palomar Observatories, I have had access to some of the finest optics ever produced. The Meade 10" f/6.3 2120 is the most impressive commercial instrument I have yet seen. Under critical examinations, stellar diffraction patterns are superb both inside and outside of focus. Focal images are sharp and crisp; in applications where high contrast characteristics are important (such as in observing the 'eyes' of the Owl Nebula, M97, or structural variations in the main spiral arm of the Whirlpool Galaxy, M51) the telescope performs impressively. The image of Saturn is beautifully defined, showing subtle belt detail and the crepe ring with surprising boldness for a 10" telescope."
—Paul Roques, Williams, AZ

Final quality control inspection.

Quality Control: As part of the final quality control inspection, an inspection which also includes detailed checkout of the telescope's mechanical and electronic functioning, each optical system is examined for any coating sleeks or scratches which may have occurred in the manufacturing process. Telescopes which pass this series of tests are then packed for shipment to authorized Meade dealers throughout the world.

Every Meade Schmidt-Cassegrain telescope must pass more than 135 optical, mechanical, and electronic tests, inspections, and quality control procedures before it is judged ready for shipment. If you're as committed to optical quality and performance as we are, then see what a Meade 4," 8," or 10" Schmidt-Cassegrain can do for your observing program. See the telescopes that combine the finest, most integrated electromechanical systems, including the revolutionary Smart Drive,™ with the highest level of optical precision in the industry today.

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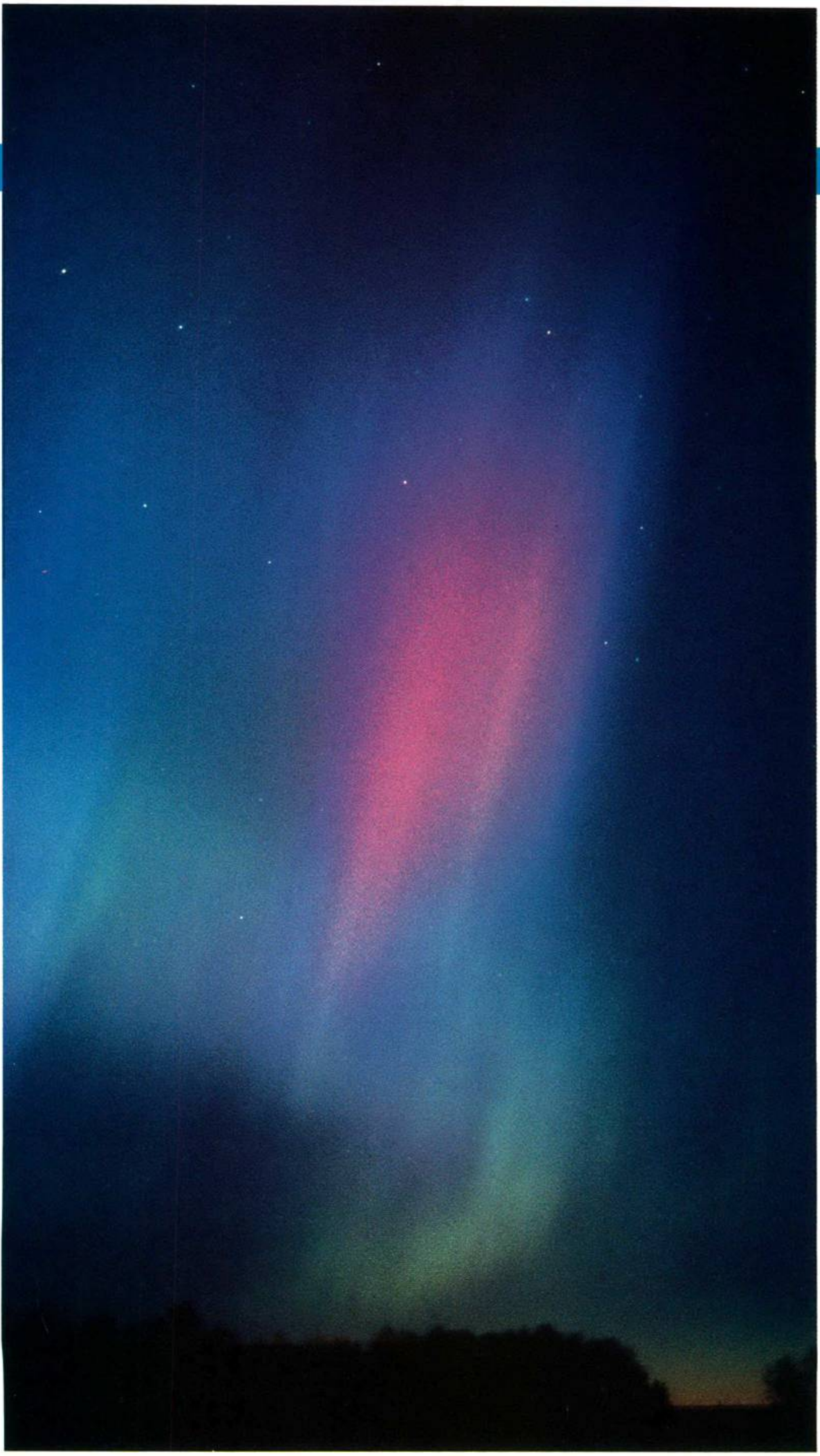
ON THE COVER: Painted with a palette of reds and blues, the Trifid Nebula is one of the summer sky's most impressive sights in a backyard telescope. It is within such nebulae that stars are born, including the Galaxy's most ubiquitous stellar members, red dwarfs (subject of the feature story "The Faintest Stars" beginning on page 26). Photo courtesy Canada-France-Hawaii Telescope Corporation, T. Gregory, photographer.



THE SKY EXPLODED with color last March as brilliant aurorae rippled across the night on several occasions. Greg Furtman captured the March 24 display using a 28mm lens at f/2 and an exposure of 20 seconds on Fujichrome 400 film. For more photos of the March aurorae, see page 77.

ASTRONOMY®

August 1991

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The
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Behind the Scenes

LAZY DAYS OF SUMMER

Long summer days at the beach or a crisp mountain retreat. Ah — what could be more relaxing! Here are three books that I recommend as perfect astronomical summertime reading.

Among the most pleasurable astronomical books published this year is Dennis Overbye's *Lonely Hearts of the Cosmos.* Overbye's book fairly vibrates with the energy and excitement of the search for and discovery of the origin of the universe. In it you will come face to face with the best and brightest cosmologists of our time, until you feel that you know them. Overbye has an intense and personal story to tell; his writing is dramatic, rich, and colorful.

But haunting *Lonely Hearts* is the enigmatic figure of Allan Sandage. The inheritor of Hubble's legacy of redshift measurements, Overbye's Sandage is brilliant but a recluse, a man at once at the heart of modern cosmology and profoundly apart.

A slightly older book, but one that will surely stand the test of time, is *First Light* by Richard Preston. Preston takes the reader on a gentle quest for the essence of observational astronomy. He opens with a section called "The Big Eye," about the 200-inch telescope, and through Preston's eyes the reader joins Jim Gunn and Maartin Schmidt as they troll for galaxies with the "Four Shooter" camera on the 200-inch.

Preston has a gift for creating a sense of immediacy, so that you feel as if you're there with him, or maybe that you *are* him. In the dome of the 18-inch Palomar Schmidt you'll share Oreos with Gene and Carolyn Shoemaker as you search for comets and feed "cookies" of film to the Schmidt camera. In the section called "Gadgeteers," you join Jim Gunn and Jim Westphal as they build the "Wiffpick" camera for the HST. It's a wonderful book to read in a hammock one hot summer afternoon.

My final recommendation for summertime reading is an oldie but goodie, Timothy Ferris' *The Red Limit.* In a fast-moving field such as cosmology, a book last updated in 1983 might be regarded as ancient history. Ferris builds his book on a bedrock foundation of history, introducing the generation of astronomers and cosmologists that precedes the one in *Lonely Hearts.* And Sandage, then a young man, shines bright in the firmament of astronomers as he pushes the Red Shift diagram toward you and whispers, "This is what nature says!"

Read these books and enjoy…

Sincerely,

Richard Berry

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Letters

It's Still Coming…

I greatly enjoyed reading "It Came From Outer Space" by Christopher Spratt (February 1991 issue) and the accounts of fireball sightings in the May 1991 letters column. Last year I was fortunate enough to experience a bright fireball. I was driving home in my car on January 6, 1990, and it was near dusk. I glanced out the driver's side window and was amazed to see a blazing orange-red fireball streaking through the broken cloud deck, leaving a grayish, smoky trail. I had to force my attention back to the road. When I glanced back a moment later, the meteor was gone. I estimated the fireball's magnitude at -8, and seeing a meteor that bright was one of the greatest moments of my astronomical observing! — *Rick Needham, Fort Ann, New York*

Earth and Moon Together

I found Neil Comins' article "The Earth without the Moon" (February 1991) interesting, but I believe his assertion that "the Moon has shielded Earth from meteoroids that would otherwise have hit us" is mistaken.

All one has to do is to consider a tennis ball ten meters away from a basketball and then imagine the effects of prolonged shotgun blasts from all directions on the system. Obviously both balls would be hit, and any degree of shielding the tennis ball could give to the basketball would be minimal. The reason why the "Moon's far side is one of the most heavily cratered surfaces in the solar system" is because it has not eroded, as Earth's surface has. — *Sumit Paul-Choudhury, Bexleyheath, Kent, England*

Neil Comins' article raises some questions about our place in the universe and the possibility of the existence of life similar to our own. It also casts new light on some apparent coincidences that typically are dismissed as unimportant.

For instance, it's amazing to me that the Sun and Moon each have an apparent diameter of about 30' as seen from Earth. One might suggest that perhaps a slight decrease or increase in the size of Earth's orbit would render our planet unsuitable for advanced life. It could be either too hot or too cold with very slight differences from today's orbital conditions. It seems that if the Sun did not have an apparent diameter close to

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- Ben Cohen, CA

"After seeing the recent ad with all the letters touting (competitive) eyepieces, I had to respond. I consider myself a very critical observer. Using a 10" f/5.6, I found the Tele Vue 40mm Wide Field superior to the (competitor) in sharpness, both center and edge. I have used very expensive and inexpensive eyepieces. I have found none optically superior to Tele Vue for astronomical purposes."
- Kenneth Drake, Observing Chairman, Houston Astronomical Society

"Your eyepiece has given me the most pleasant case of insomnia imaginable"
- Tom Lorenzin, Author of 1000 + Guide to Deep Sky Observing

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- From Observing and Photographing the Solar System by Don Parker

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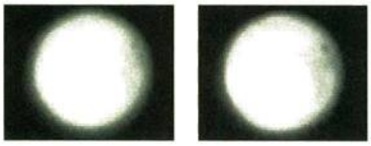
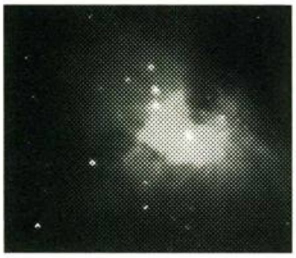


Images of Mars captured with C11



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its present one we might not be around to see it!

As for the Moon, Professor Comins argues that we would most probably not be around to "enjoy" a moonless Earth, either. Moreover, a radically different (smaller or more distant) Moon might have a different relationship to Earth — it might be a captured asteroid rather than a result of the Great Impact. So without that event, we might assume a different outcome for life on Earth.

It seems that Comins' article is an excellent reminder of the razor's edge that life on Earth has balanced upon in the past and continues to rest upon today. — *David A. J. Sargeant, New South Wales, Australia*

Young Moon Spotted

I'm writing to describe our recent sighting of a very young Moon. On March 16, 1991, at 6:57 p.m. MST, my friend Cynthia Hamilton and I spotted the Moon when it was 17h44m old. We were standing beside Arizona highway 85, about 16 miles south of Gila Bend (32.5° N, 112.7° W), looking west across the Goldwater aerial gunnery range #2. The sky was utterly clear and transparent to within 1° of the flat western horizon.

We sighted the Moon with 7x35 binoculars about 15 minutes after sunset, when it was just 5° above the horizon. We were able to follow it for more than 20 minutes, although it grew gradually dimmer and more difficult to see. The threadlike Moon consisted of an irregular but unbroken arc spanning 80°, with three brighter patches.

The contrast between the Moon and the still-bright sky was minimal. Thus, while the Moon was moderately difficult to see in binoculars, it was absolutely impossible to see by naked eye, despite the near-perfect conditions. Both of us agreed that while still younger Moons could certainly be observed with binoculars or small telescopes, we would be extremely skeptical of naked-eye reports of Moons this young and especially skeptical of reports of finding such a young Moon without first using optical aid. — *James E. Meketa, Auburndale, Massachusetts*

"Sky Almanac" in the March issue helped me find the youngest Moon I have ever seen. On March 16 my husband Alan and I took my 4.3-inch Christen refractor up to our observing ridge to search for the Moon. We were joined by fellow club member Richard Monda. Using his binoculars, shortly after sunset Rick spotted Mercury, which was near the Moon, but he could not find the Moon. I was considering giving up when, to my surprise, I swept up the slender crescent in my little refractor. Alan noted the time as 6:36 p.m. EST, giving us a Moon 15 hours and 26 minutes old.

Each of us had a brief chance to view the Moon before it vanished into the haze above the horizon, less than two minutes after we spotted it. The thin arc was quite easy to see, slightly tipped, and a bit irregular. It spanned somewhere around 90° of the lunar limb. Although a 15$^1/_2$ hour Moon is not a record, we were excited about our find. — *Susan C. French, Scotia, New York*

Life Sentence: Nintendo and MTV?

I found your letters column (April 1991) interesting as usual but was alarmed by two letters. "Is There Hope for Teenage Astronomers?" and "Back to the Basics" highlighted two problems: 1) attracting young, interested people to the field (and retaining them by removing the "nerdy" and "for boys only" labels still attached to astronomy) and 2) allowing everyone to enjoy the beauty and awe of astronomy without spending a fortune to do it.

Fortunately, a group of products in the Product Reviews section of the same issue holds the answer to these problems. By getting kids interested in astronomy computer programs, we can teach them a great deal about the subject and secure their attention without developing any nerdy qualities whatsoever. Schools, families, and organizations can use computers to show off not only space shoot-'em-ups, but quality software that will spark young people's interest and attach them to astronomy for a lifetime. — *John Neubert, director, Academic Computing, Drew University, Madison, New Jersey*

I read not only with interest but with affectionate nostalgia Thomas Pannuti's "Ballad of a Teenage Astronomer" (December 1990). I too was a teenage astronomer, back in the late 1960s. Among the most treasured memories of my youth are the long evening hours I spent in the back yard of my folks' home with my Sears 3-inch reflector. Unfortunately I grew away from the hobby in my mid-teens and am only now, at age 35, getting back into it.

I too had to endure some ribbing during my day — I recall that I sort of enjoyed it because it made me feel like an "outlaw." Some of my friends and I or-

Genesis Owner Turned Into Zombie!

Gentlemen:

I would like to say a few words about my new Genesis. I live in a relatively light polluted area, and own an 8" SCT which I have used for about two years. During this time there have been many deep sky objects which I have been unable to locate from my back yard.

I bought Genesis because I wanted a telescope that I could set up quickly to use at home on week-nights. When I began using Genesis, a few weeks ago, I was surprised to find many objects that have eluded me during the past two years. I was even more surprised when I realized that I had been looking in the right places all the time. These objects showed up in Genesis, but not in my 8" SCT.

My back yard experience with Genesis encouraged me to take it to my dark sky observing site which is, at an elevation of 5000 feet above sea level, in the Sierra Nevada Mountains. What I saw there was, in many cases, better than photographs in magazines. I was able to resolve globular clusters to a greater degree than publications indicate.

I didn't expect Genesis to be this good. It really is better than I imagined.

There does seem to be one problem with Genesis. My short week-night observing sessions have become anything but short, and I frequently arrive at work feeling and looking very much like a zombie. I guess that no telescope can solve all of your problems. In any case, thanks for the ones you did solve.

- George N. Storm, California

Photo by Jim Riffle

Unsolicited comments from warranty cards

- *It's beautiful, from case to scope.* C.C. The Netherlands
- *Fantastic! Great photo resolution, best optics ever owned and I'm a Hasselblad & Nikon fan. Now my best item.* D.B. New Jersey
- *This is my 1st scope and I'm having a wonderful time finding the limits of the instrument and my locating abilities.* G.P. New Jersey
- *Very pleased with your new improvements.* J.F. California
- *Even though cost was more than an 8" SCT with mount, quality & convenience won out. I will only use Tele Vue optics, mount and accessories.* W.B. Indiana
- *The telescope lives up to its expectation.* T.W. England
- *Wanted a 2nd telescope that was portable, delivered wide fields and superb images. Genesis is all I hoped for. The sharpness is astonishing and it's very portable.* G.H. Canada
- *Sold my 8" SCT looking for better images.* P.F. New York
- *Fantastic! My wife could not see Trapezium etc. with old scope. Now can't get her away from eyepiece: you have right to be enthused about your product.* W.J. Canada
- *I just wanted to have one excellent telescope to do astrophotography. Fantastic. Awesome.* J.J. California
- *Beautiful equipment - Total satisfaction with first use. Keep up the good work.* M.C. Ohio
- *I wanted a very high quality refractor. I was told by many - "This is it." This is a beautiful instrument!* M.F. Florida
- *Remarkable! I always wanted a 4" fluorite refractor. Sold my (8" SCT).* T.S. Indiana
- *Compactness & quality - a beautiful, fantastic instrument.* J.V. The Netherlands

- *It's the best 4" refractor made.* A.A. California
- *I was looking for the best first telescope I could buy. Something small. I never saw images clearer and more distinct than in Genesis.* G.D. Canada
- *Genesis is the only scope in the race. I wanted the best and believe I got it.* E.S. Australia
- *As the apparent equal of a (Maksutov), with the added RFT capability, Genesis is 'the', to me, obvious choice for portable astronomy. I'm completely satisfied.* R.A. Georgia
- *Very Impressive - my first view was of Pleiades with a 40mm Wide Field. The observation was remarkable, crisp, bright and jewel-like.* P.L. Massachusetts
- *The best on the market.* E.B. England
- *I bought this telescope without having seen it in-person, based on its specification & your reputation for quality. As usual, I got more than I expected with Tele Vue products...* K.L. Texas
- *My friend borrowed it & won't give it back!!* T.L. Canada
- *I wanted portability and very high quality optics. I have waited many years to be able to afford this telescope, - it was worth waiting for.* P.H. Australia
- *Superior to other 4" scopes on offer.* Z.V.S. South Africa
- *Had SCT, poor contrast/resolution. Tele Vue just the opposite, also it's more portable.* W.S. Connecticut
- *I purchased this instrument because:*
  1) Apo-refractor - basic design
  2) Tele Vue reputation
  3) Dealer owns same model U.B. Canada
- *Genesis is as good as gold...Maybe better!* F.G. California
- *I compared specs of Tele Vue vs (other high performance refractors); T-V best choice for $.* R.A. New Hampshire
- *Magic.* C.H. England

My sincerest thanks to all who've written us with such kind comments. I look forward to reading yours.

Al Nagler

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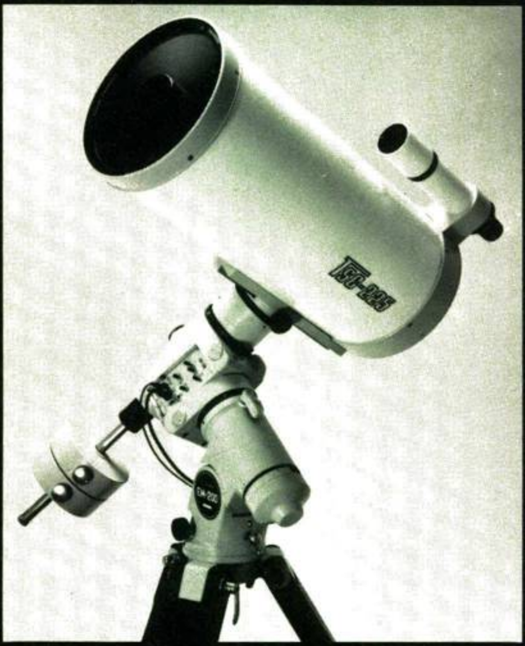

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ganized a little astronomy club and even published a newsletter for a time. My suggestion for today's young astronomers is that they keep their interest alive. It will set them apart from other people at school, but in the long run they'll be greatly better off for it. — *Kelley Dupuis, American Embassy, FPO Miami, Florida*

Blue Venus?

Congratulations on your very nice article on the Galileo flyby of Venus (April 1991). I am appalled, however, that you reproduced several images of Venus (all taken in ultraviolet wavelengths) that show Venus colored blue. Now I recognize that the majority of your readers realize that Venus is not blue and that you did this to satisfy the color-obsessed media. Nevertheless, you should have said something about the false-color nature of these images. — *Fran Bagenal, assistant professor, Department of Astrophysical, Planetary, and Atmospheric Sciences, University of Colorado, Boulder, Colorado*

— *The Galileo images of Venus were colorized by NASA. The space agency debated whether or not to tint Venus yellow, the natural color of the sulfuric acid clouds, or blue. NASA opted for blue to signify that the images were made in violet light. On page 4 of the March issue the reference to the appearance of Venus "much as your eye might see it close up" refers to the amount of detail visible, not the color. Sorry for the confusion.*

Echoes of Sam Clemens

In a recent issue of ASTRONOMY a letter to the editor from me was published (a review of Michael Kitt's article on Lunar Domes) in which the editorial staff at ASTRONOMY inserted the words "now deceased" after Alika Herring's name. I am happy to report as was the case with Mark Twain that rumors of Alika's death are greatly exaggerated. I spoke with him personally on the telephone today and can assure you he is alive and well. — *Jim Phillips, A.L.P.O. Lunar Recorder, Charleston, South Carolina* □

ASTRONOMY welcomes comments, suggestions, and additional information on articles and astronomy in general. Send your letters to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length or clarity.

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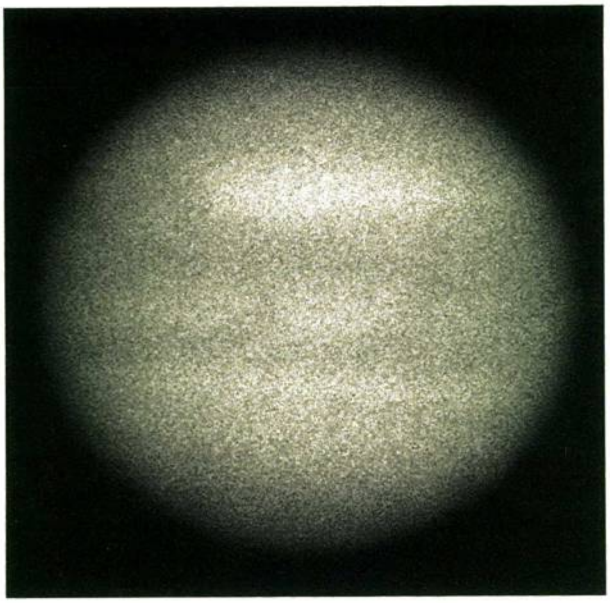
Could be Jupiter.



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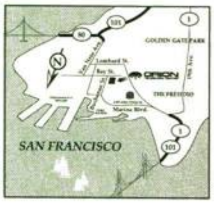

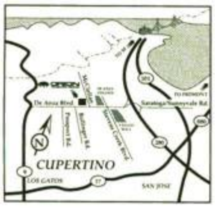

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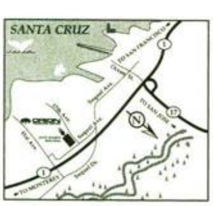

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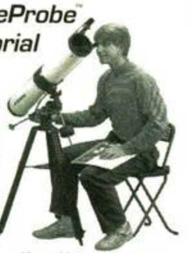

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#9496 ***$379*** (8.05)

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#9498 ***$389*** (8.05)

Orion® Sky Explorer™ Mini Deep Sky 8x56 Binoculars

56mm objective lenses gather over 2.5x the light of ordinary 7x35 binoculars. Perfect for viewing faint celestial objects, daytime viewing. Best Multi-Coated BAK-4 optics. 6° field of view. Weighs 33 oz.

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Fully Multi-Coated 3-Element Barlow lens provides superior imaging with precise color correction at three wavelengths. For maximum light transmission and highest contrast, we have used the finest quality multi-coating on each air to glass surface. 1.25" diameter.

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For use in slight to moderately light polluted areas.

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Schmidt-Cassegrain Broadband Filter–fits rear cell of Meade & Celestron SC scopes.
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52mm Broadband Filter–For 52mm camera lenses, adapter rings available for other diameters.
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SkyGlow UltraBlock Filters-Visual Only
For severely light polluted areas and faint nebulae.

1.25" UltraBlock Filter– fits 1.25" eyepieces.
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Schmidt-Cassegrain UltraBlock Filter–fits rear cell of Meade & Celestron SC scopes.
#5656 **$139** (3.67)

Orion® Color Filters for Eyepieces

Solar system observations are dramatically improved by Orion colored filters. For visual use, thread one into the barrel of any standard eyepiece. For planetary and lunar photography, Schmidt-Cassegrain owners can attach the filter to the eyepiece inside the tele-extender. Can also be threaded directly into a universal camera adapter.

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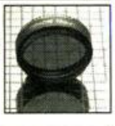
Individual 1.25" Filters-#80A Blue (#11040), #58 Green (#5540), #25 Red (#5536), #15 Yellow (#5532), #21 Orange (#5534), #47 Violet (#5538), #11 Light Yellow-Green (#5530), #82A Very Pale Blue (#5544)
$13.95 ea. (2.43)

Moon Filters



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12mm-#8596
18mm-#8597
25mm-#8598 **$44.95 ea.** (2.98)

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Organize and protect your valuable eyepieces and other accessories. This durable case with double hinges holds up to 10 eyepieces plus barlow. Die cut foam insert for snug secure fit. O.D. 8-1/2"x12-1/2"x3-1/8".
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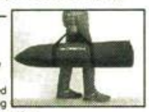

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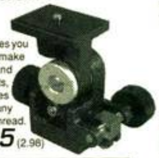

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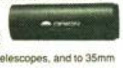

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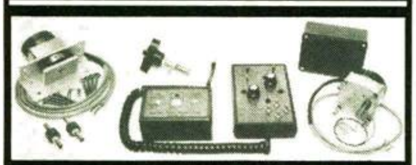

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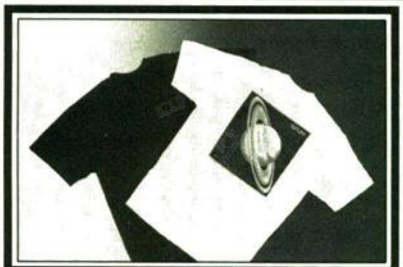

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POLICE THOSE STAR PARTIES!

by Dave Clyburn

The star parties staged by our astronomy club were becoming unruly and chaotic. Perhaps you've noticed the same trend in your own club observing sessions. Do your typical group nights consist of telescopes careening rapidly from one bright object to another — a minute on M13, another minute for the Andromeda Galaxy, a brief glance at the Ring Nebula? Observing at excessive speeds is a common infraction. Another is the stunting that some observers revel in. They claim to see targets like Palomar 4, a magnitude 14 globular cluster, in a 4-inch telescope and then have the nerve to boast for all to hear, "But it's really easy to see!"

Another insidious practice that is becoming more widespread occurs when lazy observers rush over to see an object that a more disciplined amateur has found after spending half the night star-hopping to its obscure location. Such thievery of photons is unconscionable. What's more, these parasitic observers then glance through the victim's finderscope or Telrad finder so they can sight the location of the target and quickly sweep up the same object in their own telescopes. They then add insult to injury by claiming to have found the object themselves. Such claims are illegitimate in our minds. Guilty parties should be stripped of their Messier badges.

The disorderly conduct was becoming too much to handle. The trend had to stop. To stem the tide of unruly observing, our club formed a much-feared but effective Observing Police. Their job: bring discipline and good observing skills to the uncontrolled nighttime mob. It was a tough job, but someone had to do it.

To enforce order, our Observing Police regularly patrol local star parties. Armed with red flashlights, they inspect observers and hand out citations for any observing they feel does not conform to the high standards we are attempting to instill. Citations that the Police have recently issued include:

Observing too quickly — A speed limit of 5 objects per hour is in force at our observing site. All objects must be sketched and sketches must be available for inspection during random spot checks. Penalty: Confiscation of eyepieces.

Operating a telescope in an unsafe manner — Includes bonking people on the head with the tube of a long refractor or wiring a telescope tube to a high-voltage generator to create a giant "dew zapper" effect. Penalty: Observing with said telescope.

Stunting — Such as claiming to observe invisible objects. Penalty: 30 days solar observing. A further crime is claiming to actually see detail in invisible objects. Penalty: Immediate promotion to club president.

Reckless Observing — You're guilty if you think you see objects not actually being viewed (such as exclaiming that "the Cocoon Nebula is really bright!" when the telescope is pointed at the Andromeda Galaxy). Also includes viewing objects with inappropriate filters and magnifications (such as scanning the Pleiades at 900x with an O III filter). Penalty: One night in the Coma-Virgo galaxy cluster with a 60mm telescope and an old *Norton's Star Atlas* as your only guide.

Impaired Observing — On one occasion an observer was caught trying to find an apparently interesting object called NGP. "But it's marked right here on my atlas!" he protested, not realizing the object was in fact the North Galactic Pole. Carelessly searching for deep-sky objects with a sub-aperture planetary mask in place over a Dobsonian is also subject to ticketing. Typical penalty: Tracking down all the Messier objects — in numerical order.

Impersonating an Observer — Infractions include arriving at an observing site in July with a 20-inch telescope with the intention of observing the Orion Nebula. Or owning a 20-inch telescope with digital setting circles and never looking at anything except the brightest Messier objects. Penalty: a mandatory one-night Messier marathon, *without* the digital circles.

Our Observing Police have also found a lucrative method of raising funds for club activities — mostly to purchase Nagler eyepieces for all the club executives. We now require that all observers buy observing licenses. We set the highest fees for the brightest objects. This discourages people from partaking in the tiresome and unproductive practice of observing the same bright objects over and over again. Our license fee structure is as follows:

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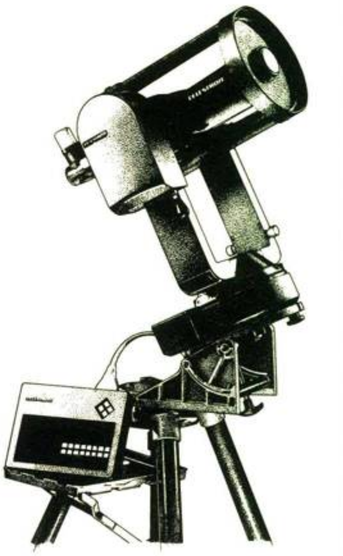

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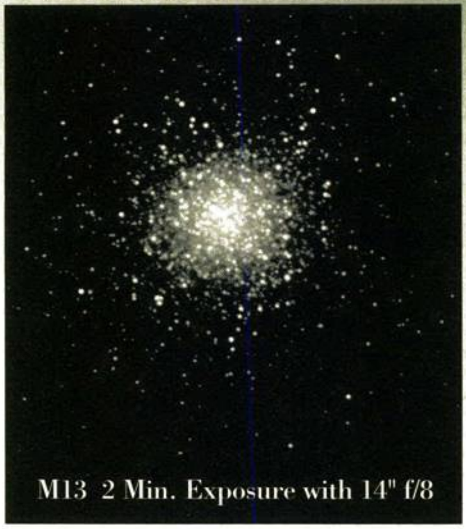

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By enforcing these regulations we have found that our star parties are now much easier to manage. Gone is the boisterous, uncontrolled enthusiasm of the past. The chaos has been replaced by quiet, disciplined observing that is a credit to amateur astronomy. Perhaps your club will follow our lead. [Club affiliation of the author withheld.]

YES, ASTRONOMY IS LOOKING UP

While long-time amateurs debate the future of backyard astronomy, unbeknownst to everyone the number of astronomy clubs has been growing by leaps and bounds. That's one of the findings from a survey of clubs conducted earlier this year by ASTRONOMY magazine.

In early January, we sent survey forms to nearly 500 astronomy clubs. A total of 281 responded this year, each with information about when the club was formed, how large it is, and what kinds of programs its members conduct. Additional data were culled from responses to previous years' surveys. Much of the raw information appeared in ASTRONOMY's annual *Astronomy Activity Guide* published as a supplement to the May 1991 issue.

The clubs we heard from this year represent a population of about 20,000 amateurs. If we add in the clubs on our database that did not return 1991 questionnaires, we get a best estimate for the total population of astronomy club members in the United States and Canada as about 35,000 people. This is roughly 20 percent of ASTRONOMY magazine's readership.

It may interest many club organizers to learn that well over three-quarters of those interested enough in the subject of astronomy to subscribe to a magazine don't belong to any club. This will be a surprise to many club organizers

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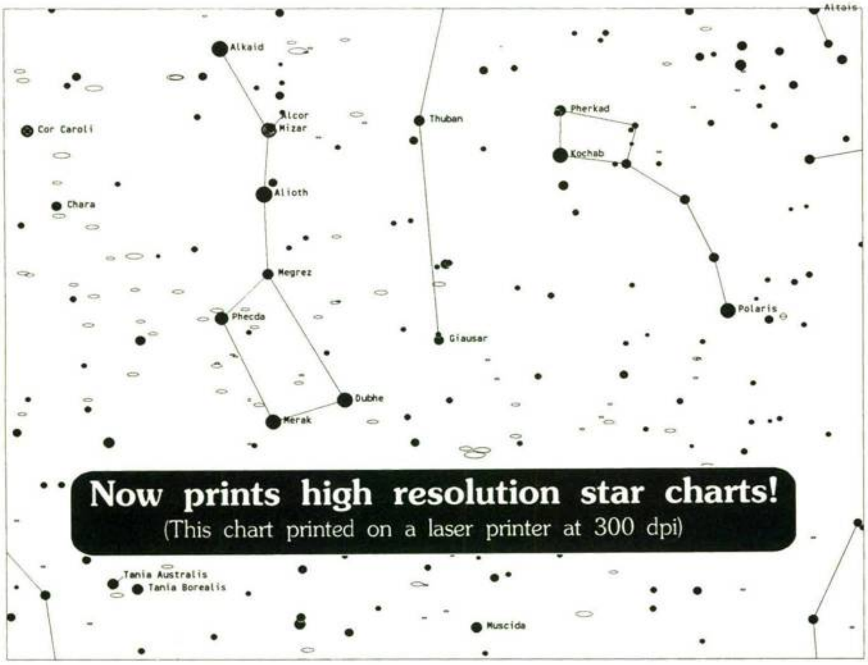

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CLUB SIZE AND YEAR FOUNDED

Year Founded	Clubs	% of Total	Number of Members	Average Club Size
Before 1950	54	17%	7,949	147
1950 – 1959	45	14%	4,427	98
1960 – 1969	36	11%	2,893	80
1970 – 1979	61	19%	3,678	60
1980 – 1991	122	39%	5,494	45
Total	**318**	**100%**	**24,441**	77

Data from 1990 and 1991 ASTRONOMY magazine survey of U.S. and Canadian astronomy clubs.

since club people often have the impression that the universe of amateur astronomy revolves around club activities. But for most folks that consider themselves amateur or backyard astronomers, this just isn't so. Our survey shows that for every astronomy enthusiast who belongs to a club, there are four others who aren't members. This untapped audience represents a challenge to clubs everywhere. The interest is out there. The people are out there. It's up to the creativity and efforts of club members to reach them.

In fact, an unknown and perhaps even larger number of astronomy enthusiasts don't belong to any club or subscribe to *any* astronomy magazine! And that's a challenge for us in the magazine business. Unfortunately, our survey couldn't tell us what the size of that potential audience is. Based on book and telescope sales, some estimates put the population of backyard astronomers in the United States and Canada up around the 500,000 mark. And that may be conservative.

Perhaps the most surprising result of the survey is that nearly 40 percent of all the astronomy clubs in the United States and Canada have formed in the last ten years. (Fully 60 percent of the clubs in existence today formed since 1970.) Most of the newest clubs are small, with an average size of 45 members. These friendly groups (presumably they're friendly!) are springing up in small communities or as alternative second or third clubs in large cities.

Our survey also shows, as you might expect, that the larger clubs are generally the older, well-established organizations serving major metropolitan areas. The average club size is about 80 members, but this conceals a wide range. Some clubs have only 5 or 6 members — they are more like conversation circles. At the other extreme, the largest astronomy club on our database is the Toronto Centre of the Royal Astronomical Society of Canada with its 1,000 members. The oldest astronomy club on our list is the Chicago Astronomical Society, founded in 1862.

Not surprisingly, our survey also reveals a correlation between club size and the annual dues. Larger clubs, with their greater services and activities to support, have higher dues. However, only six clubs had dues of $40 or more. In small clubs the dues are minimal or non-existent. The most popular range of annual dues was $10 to $19.

Some clubs are very active at reaching out to the public. For example, out of the 227 clubs that responded to the question, 85 percent said they conduct some type of Astronomy Day activity, a good measure of their public-mindedness. Out of the same number of clubs responding, 43 percent said they conduct some type of light pollution awareness program in their community. This is becoming an increasingly important activity for astronomy clubs since they are often the only groups in a community who are keenly aware of the problem of waste lighting and who have the incentive to do something about it or at least to raise the issue in a public forum.

Many clubs have observatories and use them as a focus for their members' programs and public activities. Out of 240 clubs that answered whether or not they have an observatory, 55 percent said they do. The size of the average telescope in a club-run observatory is 16.5 inches. Just under 80 percent of the clubs that have observatories open them to the public at least once a year, with many conducting regular weekly or monthly public viewing nights. This represents a tremendous volunteer force

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for public education in astronomy. The community programs that clubs conduct are a main entry point for bringing new people into the hobby of astronomy, a fact that clubs themselves don't often appreciate.

The survey presents us with some good news, along with some challenges. If the sheer number of clubs is a gauge, the hobby is flourishing. And club statistics give us just the organized tip of the iceberg. The numbers demonstrate that astronomy as a hobby is more popular today than ever before. And from what I've seen at club meetings, astronomy courses, and star parties, interest in the hobby today extends to a wider range of ages (and to more women) than it has in the past.

Of course, we've all heard assertions that the public is more ignorant of science and less interested in it than they were a few years ago or that light pollution is killing the hobby or that TV and rock videos keep kids away from science. I think there's very little evidence for these claims and a great deal of evidence to the contrary.

For example, compare the public's interest in Voyager's flyby of Neptune in 1989 to their interest in Voyager flybys of Jupiter or Saturn a decade earlier. How many of us even saw those encounters on live TV? Compare the public's interest in the Mars opposition in 1988 to the level of interest exhibited at the previous good opposition in 1971. How many people did you have lined up at your telescope wanting to see Mars in 1988? Or to see Comet Halley in '86? I think these events show that the level of interest in and knowledge of astronomy in the public is as high as it's ever been.

To wrap up, if yours was one of the clubs that returned a survey to ASTRONOMY this year, we thank you for taking the time to do so. If we missed you, chances are we haven't heard from your group for a while and the address we have for your club is out of date. Please be sure to update us.

In the meantime, have a happy summer of stargazing. Be sure to check out the star parties, Perseid meteor watches, and public viewing nights being staged in your area by outgoing clubs and community-minded planetariums and observatories. (Don't worry, you won't actually have to contend with Observing Police at any star party!) See the May 1991 issue of ASTRONOMY for information about the club or astronomy facility nearest you.
— *Alan Dyer* □

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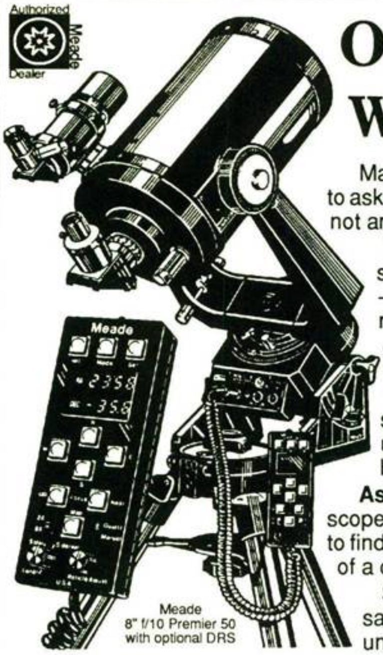

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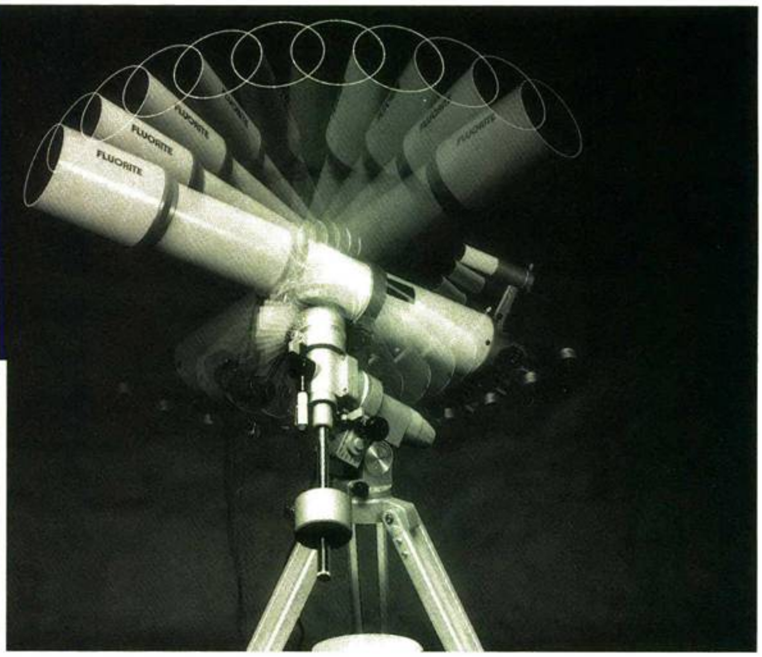

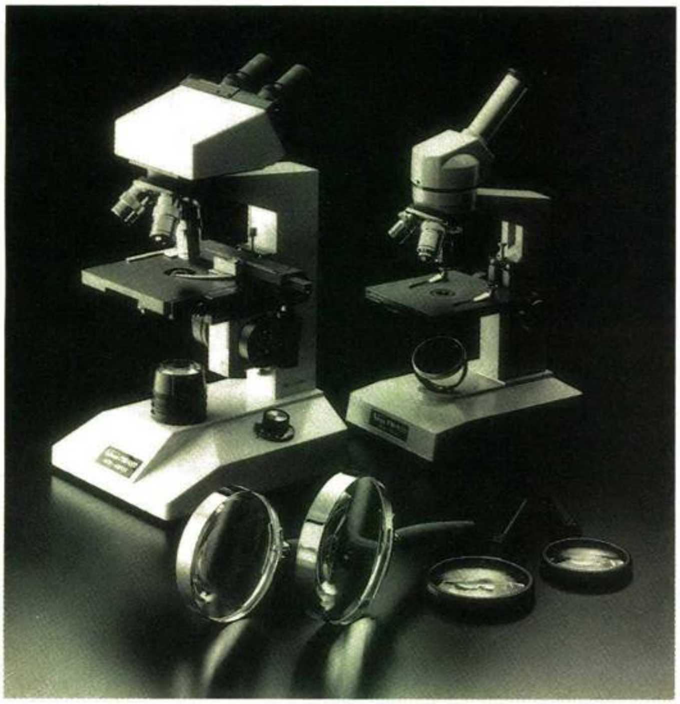

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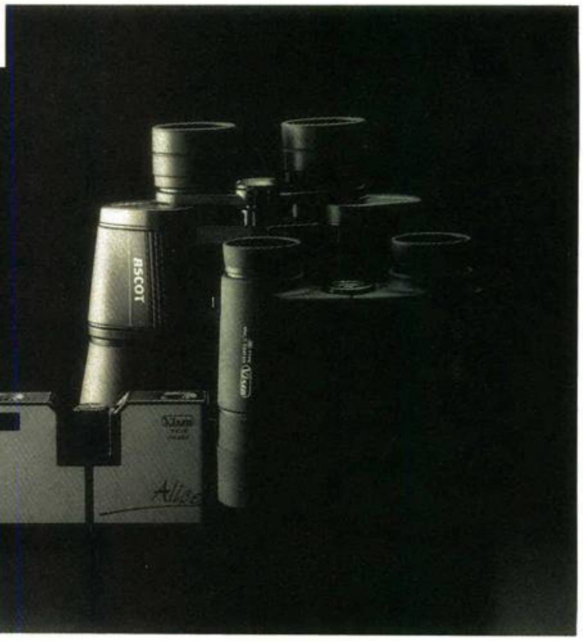


SOMETHING NEW IN THE GALAXY'S CENTER

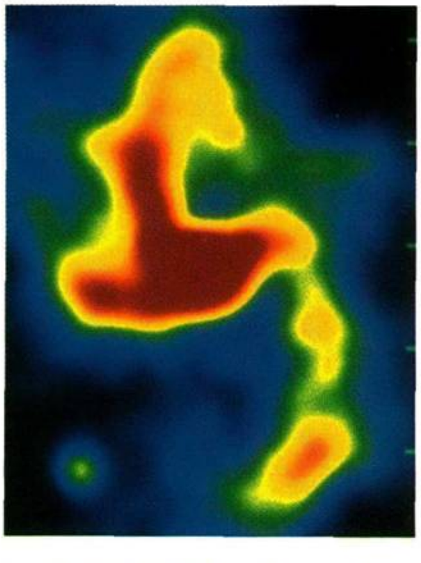
Astronomers have discovered an enigmatic source of radio radiation near the center of the Galaxy. The source, which had never been seen before despite intensive observations of the region, appeared suddenly and has since fluctuated widely in brightness.

A team of investigators found the object while using the Very Large Array radio telescope in New Mexico to monitor variations in Sagittarius A*, the powerful radio source located at the center of the Galaxy. The new source first appeared on an image taken December 28, 1990; an image taken December 11 showed nothing unusual. The object is a point source and lies 35 arcseconds, or approximately 4 light-years, southeast of Sagittarius A*.

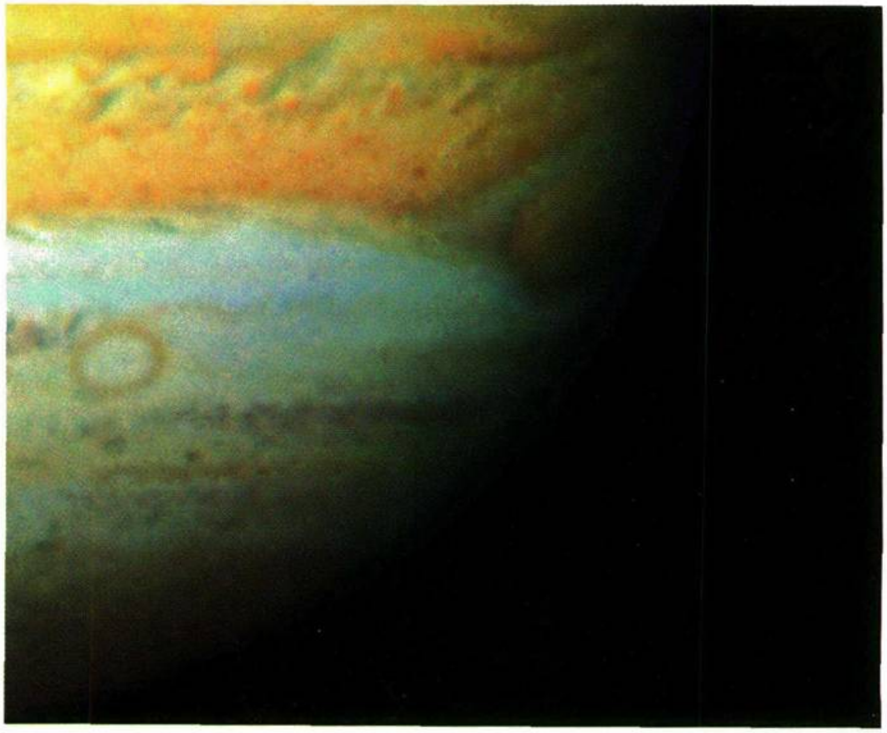
From the initial observation in late December through mid-April (the last observation available), the astronomers observed the galactic center eleven times. And each time the source displayed a different strength. At its maximum in late January, the source at a wavelength of 20 centimeters appeared at least as strong as the galactic nucleus! So far the object has been seen only at radio wavelengths — observations at optical and infrared wavelengths have shown nothing because those wavelengths cannot penetrate the huge amount of dust that lies between Earth and the galactic center.

Observations at three different radio frequencies show that the emission comes from high-speed electrons moving in a strong magnetic field, a process called synchrotron radiation. However, the nature of the source remains a mystery. Two possible explanations — that it is a supernova or a recurring nova — don't jibe with the observed characteristics of the source.

For now, the investigators are continuing to monitor the source to see how it changes. They have also used the partially completed Very Long Baseline Array radio telescope to get images of the source with extremely high resolution. But so far the questions raised by this enigmatic source far outstrip the answers.



A BAFFLING NEW OBJECT has been found at the center of the Milky Way. The new object (seen as the point source at lower left in this VLA image) lies just 4 light-years from the nucleus of the Galaxy, Sagittarius A*, which is hidden by the strong radiation surrounding it. In this false-color image, red represents the strongest emission while blue is the faintest. Courtesy NRAO/AUI.



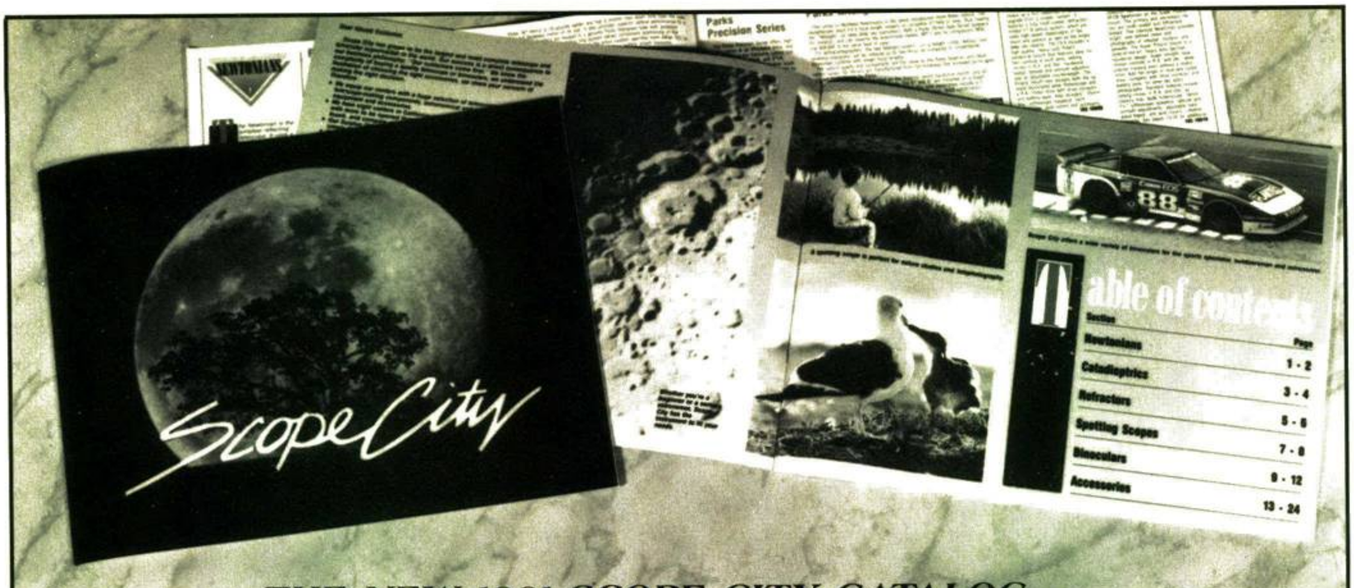
A STRIKING PAIR OF SPOTS highlights the Space Telescope's first image of Jupiter. Taken on March 11, 1991, by the Wide Field/Planetary Camera, the image clearly shows a white oval (left) and the Great Red Spot (right), which is poised to rotate out of view beyond the southeastern edge of the planet. With a resolution of 0.15 arcsecond, this photo is as sharp as Voyager images taken 5 days before closest approach. Such highly detailed images will allow astronomers to continue the monitoring of Jovian wind velocities begun by Voyager and to expand the observations to ultraviolet and infrared wavelengths. NASA photo.

10-METER KECK TELESCOPE TO GAIN TWIN

The 10-meter Keck telescope, now nearing completion on the island of Hawaii, will soon have a 10-meter twin. The W. M. Keck Foundation announced a $74.6 million grant to fund 80% of the cost of the second giant telescope to be built beside the first Keck telescope, now called Keck I.

Construction of the second telescope is scheduled to begin in early 1992, about the time that the Keck I becomes fully operational. Keck II should begin operation in 1996.

The second 10-meter Keck telescope is patterned after the first. It will feature the same segmented-mirror design, which combines 36 thin, hexagonal mirrors that function as if they were a single mirror 10 meters (33 feet) in diameter. This revolutionary design was proven to work in tests made in December 1990



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with the Keck I telescope (see "Keck's First Light," April 1991).

Keck II will be built adjacent to its sister telescope at an altitude of 13,600 feet atop Mauna Kea, a dormant volcano on the island of Hawaii. The site is considered the best in the world for astronomical research because of its clear skies and excellent seeing.

Just as the Keck I telescope is, the Keck II telescope will be built and operated by the California Association for Research in Astronomy (CARA), a partnership of the University of California and Caltech. The two institutions will share the majority of the observing time on the two telescopes, and the University of California will contribute to operating costs.

Among the benefits of building two telescopes 85 meters apart, at opposite ends of the same observatory building, are doubling the light collecting power and the ability to perform optical and infrared interferometry, according to Edward C. Stone, chairman of the CARA board of directors, director of the Jet Propulsion Laboratory, and a vice president of Caltech.

"Gathering twice as much light will make possible the study of fainter, more distant galaxies, quasars, and primitive galaxies as they appeared in the first few billion years of the universe," Stone explained. Collectively, the two telescopes will have eight times the light-collecting power of the 200-inch Hale Telescope at Palomar Observatory.

Although the telescopes will often be used separately, they will sometimes be used together for interferometry in the infrared part of the spectrum. Light from the two telescopes will be combined just as signals from radio

Amateur News

WEST COAST ASTROPHOTOGRAPHERS MEET

On March 30, 1991, Astrophoto IX was held in Thousand Oaks, California. This year's meeting, sponsored jointly by the Ventura County Astronomical Society and the Orange County Astronomers, drew about 250 amateur astronomers and astrophotographers eager to talk to other enthusiasts, see displays of astrophotos, and swap tips, ideas, and equipment.

The meeting's main attraction each time is the contributed talks given by expert astrophotographers. The program this year included talks on using unsharp masks to extract detail from negatives (by Chris Schur), a simple-to-build tracking camera mount (Hal Jandorf), solar eclipse photography (Carter Roberts), and using Konica 3200 film in a 6x7 format camera (John Sanford).

New electronic techniques also made an appearance: Michael Stecker spoke about using the Santa Barbara ST-4 Star Tracker CCD camera for long exposures on deep-sky objects, and ASTRONOMY's Richard Berry spoke about the optimum f/ratio to use with CCD cameras for taking photos of lunar and planetary subjects. He also demonstrated the virtues and power of image processing. "The raw image is just the beginning!" he said.

Several vendors exhibited some interesting products, among them Hollywood General Machining with their new massive Losmandy mounting. Celestron showed off a new array of eyepieces and a 2-inch prism star diagonal, and SpectraSource Instruments exhibited their CCD camera systems.

A big benefit of the Astrophoto symposiums (which meet every other year) is that they provide chances of meeting new people and renewing acquaintances. People who know each other only as names in print can meet and talk about equipment, sky conditions, and new ideas.

The astrophotos on display were impressive, among them Chuck Vaughn's H-alpha filtered photos, Kim Zussman's work done with his custom $14^1/_2$-inch f/8 Cassegrain, and Chris Schur's unsharp-masked photos. Many other astrophotographers also showed their work and contributed to an interesting and educational day. — *Tony Hallas*

DISPLAYS, EXHIBITS, AND TALKS about astrophotography were highlights of the ninth Astrophoto seminar, held in Thousand Oaks, California, in March. Tony Hallas photo.

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dishes are combined for making high-resolution radio maps of the sky. Together the two telescopes will have a resolving power of 10 milliarcseconds, which is comparable to resolving a car's headlights from a distance of 16,000 miles. With this resolution, they will study star formation regions and map the distribution of matter around forming stars. The twin Kecks should have sufficient power to identify warm Jupiter-sized bodies in orbit around the 100 nearest stars.

Keck Foundation Chairman, President, and Chief Executive Officer Howard B. Keck said, "The technological breakthroughs achieved with the building of the first Keck telescope have encouraged us to push further the boundaries of astronomical research that will only be possible with a second telescope."

RADIO IMAGES REVEAL HIDDEN ARCS IN ORION

A Northwestern University radio astronomer has discovered unexpected new structures at the heart of the Orion Nebula. Using the Very Large Array radio telescope near Socorro, New Mexico, Farhad Yusef-Zadeh has discovered that the Orion Nebula's center contains a network of arcs and filaments, some of which are about 1.5 light-years long. Such large structures have not been found in other star-forming regions. The new features are composed of ionized gas and surround the bright cluster of stars at the nebula's center known as the Trapezium.

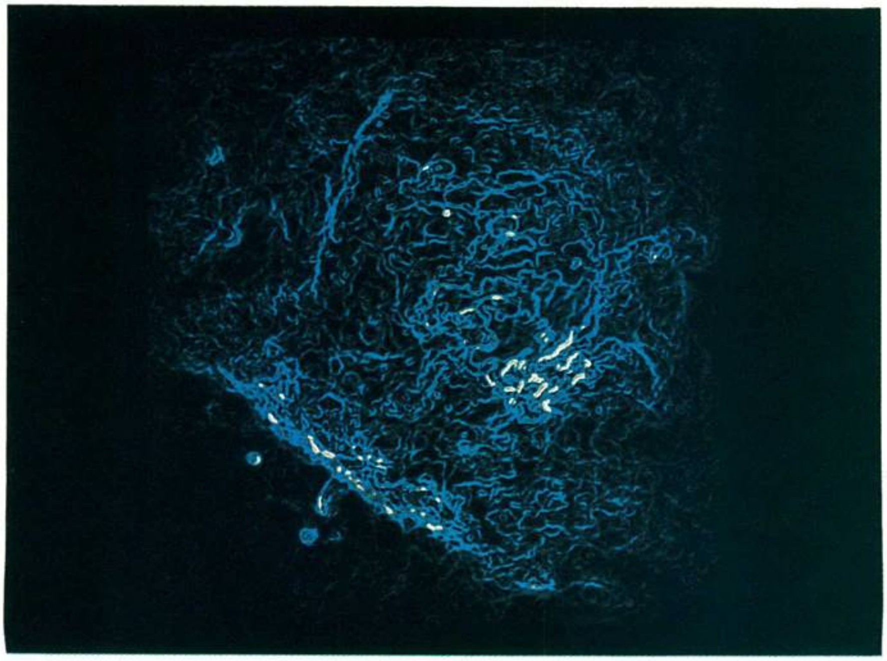
Prior to Yusef-Zadeh's discovery, researchers thought that the material inside stellar nurseries like the Orion Nebula would be distributed relatively smoothly. Theories that described the behavior of gases in proto-stellar nebulae hadn't predicted such intricate arcs.

There are two possible explanations, Yusef-Zadeh explains. The arcs and filaments could be formed when ultraviolet radiation from the stars in the Trapezium ionizes the surrounding gas. The heated, ionized gas would then expand to form the radio-emitting filaments.

Another explanation attributes the arcs to powerful collisions that occur when hot gas rushes out of the luminous stars in the cluster and races through the surrounding layers of cooler, denser gas. The resulting shock wave would push aside the cooler interstellar gas, creating cavities where the material is swept up and filamentary arcs where the material converges with other expanding shock waves.

"We've really just scratched the surface of the arcs and filaments," Yusef-Zadeh comments, adding that it's too early to tell how the discovery of these new structures deep inside Orion will affect theories about the origin of stars. He will be returning to the Very Large Array to take a closer look at the Trapezium area to determine the role of stellar winds in the creation of the filaments and arcs. Meanwhile astronomers are looking at other nebulae to see if they contain structures like the arcs of Orion. — *Joseph Baneth Allen*

THE CORE OF THE ORION NEBULA has an unexpected filamentary structure revealed by new observations with the Very Large Array radio telescope. Radio image courtesy Farhad Yusef-Zadeh.



COSMIC CLOCK MAY SHOW GRAVITY WAVES

A pair of massive, dead stars circling one another at up to a tenth the speed of light may be the most precise cosmic clock yet discovered for studying the nature of gravity. The binary system called PSR 1534+12 is made of two superdense neutron stars, one of which is a pulsar that emits 26 precisely timed radio pulses every second as it spins on its axis. Reported in the April 25 issue of *Nature*, PSR 1534+12 was discovered by Alexander Wolszczan at the National Astronomy and Ionosphere Center in Arecibo, Puerto Rico. Wolszczan's new binary pulsar provides a tool for testing Einstein's theory of relativity and the gravitational radiation it predicts.

Each of the two neutron stars contains about 1.3 times the mass of the Sun squeezed into a sphere only 10 miles in diameter. Like a pair of spinning dancers, the two stars circle one another every 10 hours at a separation of only 800,000 miles. This is just over three times the distance from Earth to the Moon. Their orbital speed of 900,000 miles per hour is so fast and the stars are so massive that their orbital dance should bounce the "stage" of space-time itself, creating waves rippling out from the dense duo — the gravity waves predicted by Einstein.

Although other binary pulsars have been found, PSR 1534+12 is one of the nearest known. Its distance of only 1,500 light-years makes for sharp, strong signals that should allow astronomers to make measurements of the pulsar's timing that are 10 times more accurate than those made with previous binary pulsars. As the neutron stars orbit each other and emit gravity waves, the waves should carry away some of the system's energy. As a result, the pulsar's ticking radio beacon should slow down. Detection of this change would tell astrophysicists about the existence and nature of the long-sought gravity waves.

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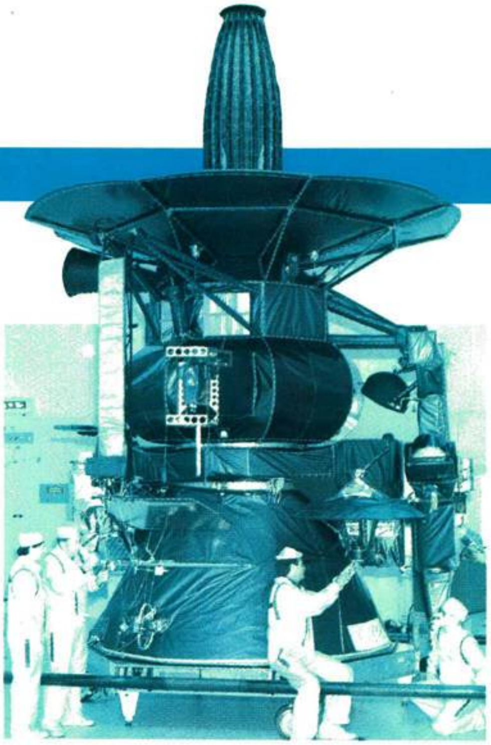
Space News

GALILEO IN TROUBLE



GALILEO'S ANTENNA is giving the multimillion dollar spacecraft a potentially serious problem. When it is stowed the antenna ribs connect at the top of the mast. Apparently, some of these have not released, jeopardizing the mission. NASA/JPL photo.

An emergency spacecraft may have to be sent to Jupiter to save the Galileo mission. That's the last-resort solution to the first major problem to face the Jupiter-bound Galileo.

On April 11, engineers at NASA's Jet Propulsion Laboratory commanded Galileo's main antenna to unfurl from its stowed position. The antenna had been folded up like an umbrella since the October 1989 launch to protect it from the heat of the Sun as Galileo flew through the inner solar system, making its passage by Venus. However, the engineering data indicate that the 16-foot-diameter antenna did not unfold as it should. A slight wobble in the spin of Galileo tells engineers that the antenna has not unfolded symmetrically — one side is open but the other side is still caught at the top of the central antenna mast. (The antenna was last unfurled in July 1989 during pre-launch tests.)

Since the trouble developed engineers have been attempting to duplicate the problem with a mock-up and with computer simulations. Ironically, after all the special precautions that spacecraft designers took to keep the antenna shaded, the best theory (as of mid-May) is that the antenna structure has become *too* cold. The balky ribs have stuck in place as the central antenna mast contracted. By turning Galileo to expose the antenna to direct sunlight, engineers may be able to free the stuck ribs.

However, computer simulations show that it won't be possible to heat the antenna enough to free the antenna until Galileo comes within 1.2 AU of the Sun. This occurs in late 1992 as Galileo again approaches Earth in preparation for the December 8 flyby, the second such Earth encounter needed to boost its velocity before heading out to Jupiter.

Another possibility is that the antenna structure became too hot near the Sun and as a result some of the adhesives used are causing the antenna material to stick. If this is the case, then cooling the antenna to make the adhesives become brittle and lose their stickiness is the solution. The best opportunity for this fix occurs in January 1992 when Galileo is farthest from the Sun (at 2.3 AU) in its current orbit. However, early tests seemed to rule out the "too-hot" theory.

Should the antenna remain stuck for this October's flyby of the asteroid Gaspra, then Galileo scientists and the rest of the world will be denied a first "live" close-up look at an asteroid. The smaller, low-gain antenna that has been used so far could not transmit data fast enough to send back real-time images and data. Instead, all the science would be stored on the tape recorders on board Galileo for playback when Galileo returned to the vicinity of Earth in late 1992. This was the procedure used to gather the Venus flyby data in 1990. No science would be lost at Gaspra; we would simply have to wait a while to see it. In addition, the balky antenna will not affect any of the observations and images planned for the Earth-Moon encounter in December 1992.

However, the problem at Jupiter is more serious. If by arrival at Jupiter in December 1995 the high-gain antenna is still not usable, then data could only be transmitted back through the low-gain antenna at the ponderous rate of 10 bits per second (compared to the high-gain antenna's rate of 131,000 bits per second). At the high-speed transmission rates Galileo can send back one black-and-white image per minute. By comparison, the first mission to fly past Mars, Mariner 4, sent back information at 8 bits per second, a rate that required 8 hours to send one picture made of 200 by 200 pixels. Galileo's cameras use an 800- by 800-pixel array and produce 16 times the amount of data in each image. It would take days to transmit a single image.

When the problem first arose, JPL engineers proposed a possible last-ditch solution: build a special satellite just for data relay (one modeled after the Tracking and Data Relay Satellites NASA has in orbit around Earth), put it on a fast rocket to Jupiter, and place it in orbit around the giant planet, preferably before Galileo gets there. According to William O'Neil, Galileo Project Manager, "So far Galileo has worked beautifully. If the only thing we were lacking at Jupiter was the antenna, then it might be worth sending a specific relay satellite." Such a satellite would have to be launched no later than early 1993 to get there before Galileo.

However, the relay satellite could arrive after Galileo. Galileo could be placed into a parking orbit around Jupiter where it would use up very little attitude control fuel. It could idle indefinitely until the relay spacecraft arrived in orbit. This option would delay the Jovian tour and the major flow of data, possibly until late in the decade. That's a trying prospect considering the Galileo project's long history of delays.

But these are all sketchy ideas — as O'Neil told ASTRONOMY in mid-May, "We haven't even put the relay satellite plan on paper." Scientists hope it won't be necessary to do so. Over the summer, engineers will be concentrating on the possible simple solutions. Serious planning for the elaborate relay satellite plan won't be started until early next year and then only if the plan is judged by NASA as the best solution. ☐

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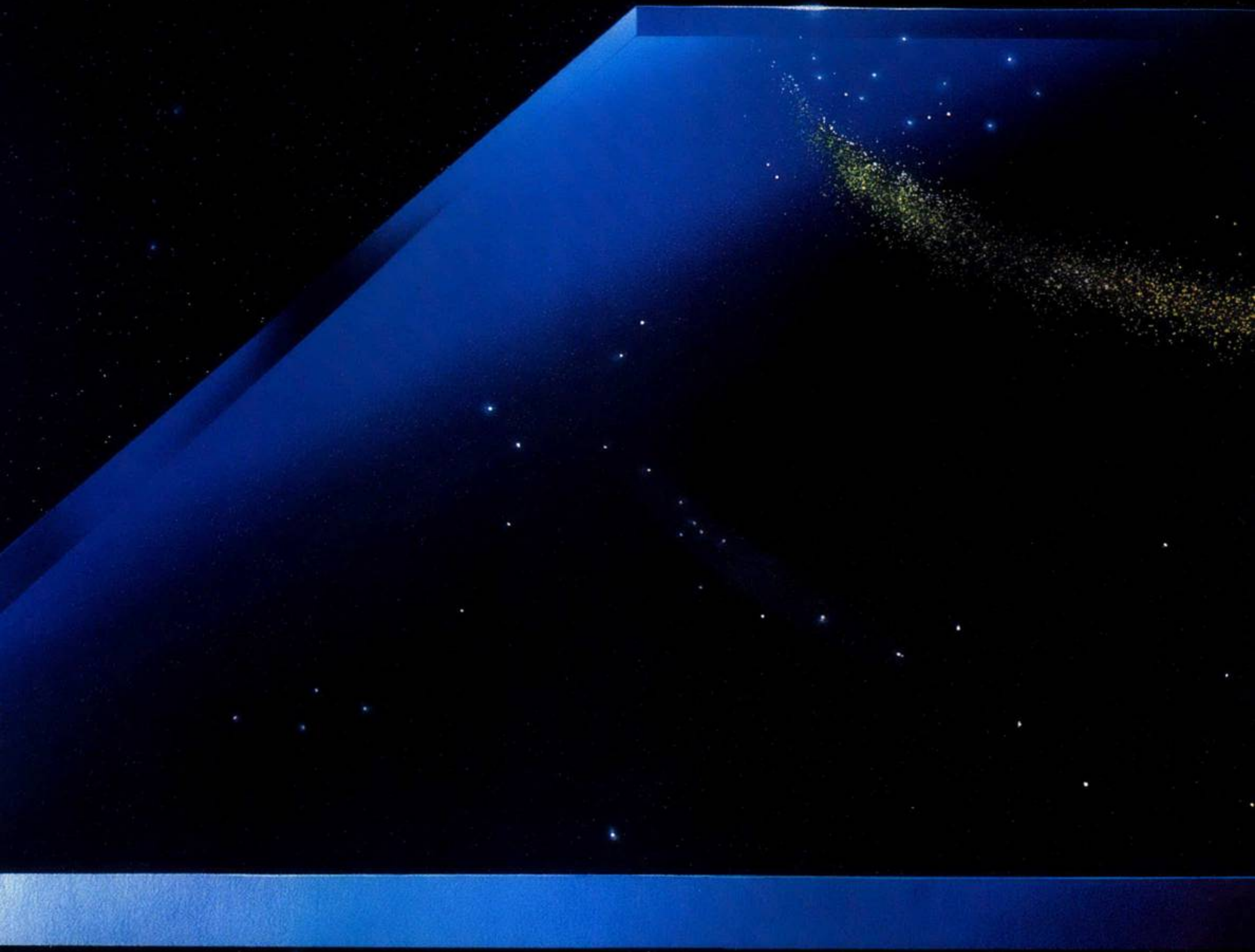

THE FAINTEST

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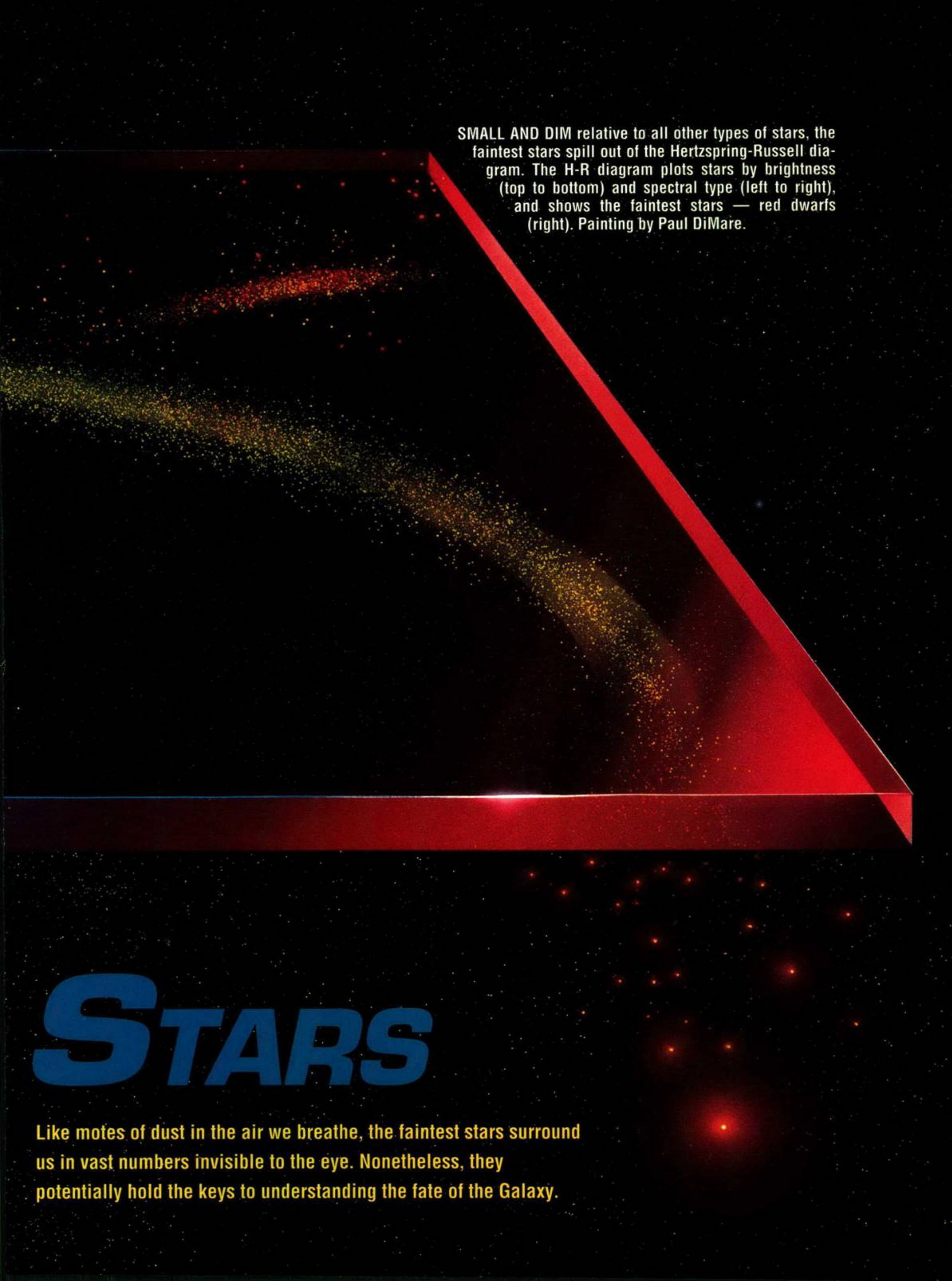


SMALL AND DIM relative to all other types of stars, the faintest stars spill out of the Hertzspring-Russell diagram. The H-R diagram plots stars by brightness (top to bottom) and spectral type (left to right), and shows the faintest stars — red dwarfs (right). Painting by Paul DiMare.

STARS

Like motes of dust in the air we breathe, the faintest stars surround us in vast numbers invisible to the eye. Nonetheless, they potentially hold the keys to understanding the fate of the Galaxy.

“Ordinary folks must be the best kind,” said a young lawyer named Abraham Lincoln. “That’s why God made so many of them.” If this could be said of stars, then the faintest stars must be the best kind.

Thus far we’ve looked at the hottest stars (February 1990 issue), the coolest stars (May 1990), the largest stars (October 1990), and the brightest stars (May 1991). We’ll now turn our attention to the faintest, a class of stars that appears inauspicious and unimportant at first glance but one that teaches us about the behavior of distant suns and perhaps even the fate of the Galaxy itself.

Although they are dim, small, and invisible from far away, the faintest stars outnumber all others. They also burn their nuclear fuel in a leisurely way, sitting in space like dim embers in the corner of a fireplace. Because of this, they will outlast larger stars, which convert hydrogen into helium at a furious rate. What the faintest stars lack in brightness they make up for in sheer numbers, contributing fully half of the mass of the Galaxy! These objects constitute a silent but powerful majority.

The significance of the faintest stars is now clear to astronomers, but our knowledge of them has lagged behind that of their brighter siblings because their faintness makes them difficult to observe. But more and more astronomers are gaining telescope time to pass into the shadowy world of the dim.

Life at the Bottom

Living at the bottom of the main sequence is a dubious distinction. Because these stars have very low mass and luminosity, hardly anyone knows they are there unless they are relatively close by. But just what do they look like if we’re up close? For comparison, consider Proxima Centauri, the closest star to the Sun and a textbook red dwarf. The Sun’s absolute magnitude, its true brightness, is 4.8, and Proxima’s is eleven magnitudes fainter, making it a mere 1/26,000th as bright. (And the Sun is not a particularly brilliant star.) From an Earth-like planet orbiting Alpha Centauri, the brightest star in the Alpha-Proxima system, Proxima would appear as a 4th-magnitude dot of light, rivaling the stars in the handle of the Little Dipper and outshone by hundreds of other stars in the sky. Proxima isn’t the most extreme case, either. If the Sun were replaced by LHS 2924, one of the faintest stars currently known, our star would appear fainter than the Full Moon — we would have trouble reading outdoors in full sunlight.

Down in the Chilly Depths

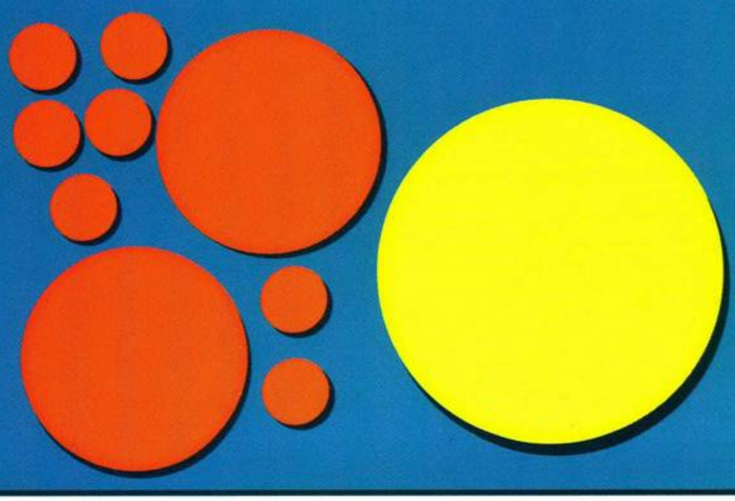
To be fair to the faintest stars, however, we also need to look at their temperatures. After all, they are very cool — much cooler than the Sun. Temperatures of the faintest stars range from 3900 kelvins for Eta Cassiopeiae B downward to maybe as low as 2200 K for LHS 2924. At such chilly temperatures the stars radiate most of their energy in the infrared, where we cannot see it. To judge such a cool star’s brightness we need to look at its bolometric magnitude, a measure of the star’s brightness in all wavelengths. The difference between the bolometric magnitude and the ordinary visual magnitude is called the bolometric correction. (The value of this correction depends strongly on a star’s temperature.) For the 6000 K Sun the correction is a mere 0.08 magnitude, but at spectral type M0 (near 4000 K) it is about 1.5 magnitudes, and for a star like LHS 2924 it is nearly five magnitudes. So in reality these stars are about five magnitudes, or 100 times, brighter than we see them. Only about 1 percent of their energy is visible to the human eye. That certainly makes the faintest stars a little — but not much — more respectable.

Why are these stars so faint? Their low luminosities are a consequence of their small diameters. The sizes range from about 65 percent that of the Sun for large faint stars to only 3 percent — about 1/3 the size of Jupiter — for LHS 2924. At the Sun’s distance, LHS 2924 would be only 1′ across, just barely discernible as a dim red disk. By comparison, the Sun measures 33 times larger in our sky.

The low temperatures and small diameters have a powerful impact on the appearance of the stars’ spectra. These red dwarf stars are cool enough to allow the formation of molecules, particularly titanium oxide, whose absorption bands can attain great strength in red giants and supergiants. This is even more pronounced in red dwarfs. The small diameters result in high gas pressures, which promote the formation of molecules, rendering the spectra of the cool dwarfs quite complex. We even see the formation of three-atom molecules like calcium hydroxide (CaOH). The general faintness of the stars complicates the matter further, making it quite hard to obtain high-quality detailed spectra. In-

The Most Plentiful Stars

Although they are only a fraction as luminous as most stars, red dwarfs are so numerous that they make up over 50 percent of the mass of the Galaxy. Red dwarfs have diameters ranging from 65 percent that of the Sun’s down to 3 percent. They are much fainter than the Sun; Proxima Centauri, for example, puts out only 1/26,000 as much light as our star.



The Odd Behavior of Faint Stars

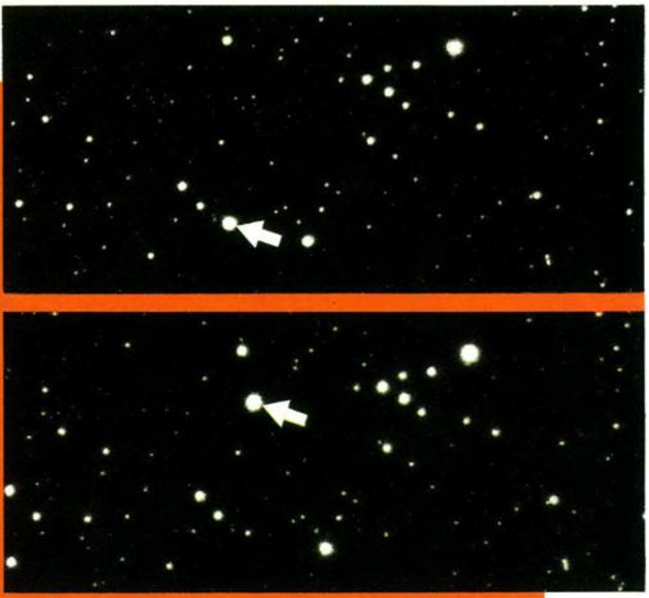
What can a bunch of nondescript faint stars tell astronomers about the Galaxy? Plenty. Because many of the faint stars are close by, they appear to move across the sky relative to more distant stars.

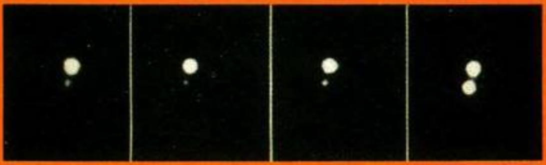
Barnard's Star (right) shows a wobble in its motion that may indicate massive planets encircling it.

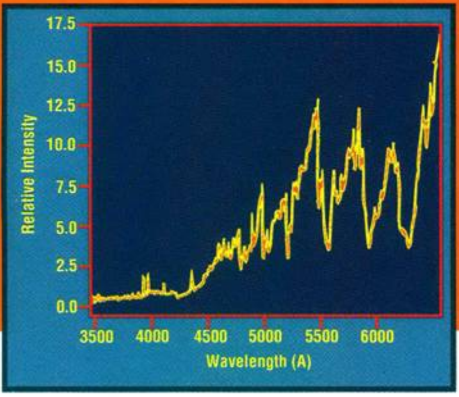
Proxima Centauri (lower right), the closest star, periodically flares in brightness.

The erratic flare star UV Ceti has a complex spectrum (bottom) and belches bursts of energy that can brighten the star by a magnitude in just one minute.

Such a flare is visible in the sequence below showing DO Cephei.







deed, the difficulties are such that the whole concept of spectral classification begins to break down. The spectral standards for red dwarfs only extend to type M5.5, yet there are stars cooler than this, and astronomers can only guess within this deep and dark realm.

The choppy nature of these stars' spectra, coupled with the fact that most of the radiation is in the infrared, makes it difficult to determine temperatures. The situation is not too bad for hotter subclasses, but we are not at all sure of the temperatures at the bottom of the main sequence. For example, LHS 2924's surface temperature of about 2200 K includes an uncertainty of about 300 K each way, an uncomfortably high possible error.

Senile Stars

The most important characteristic of the faintest stars is their mass, the characteristic that controls the rate of thermonuclear burning and the luminosity and, consequently, the diameter and temperature. The larger the star's mass, the greater the heat in the core. The Sun's core temperature is 15,000,000 K, far above the 5,000,000 K minimum required for the fusion of hydrogen into helium. As a star's mass drops, so does its central temperature. Eventually, the temperature is low enough that hydrogen atoms can no longer fuse to make deuterium, the first step of the reaction chain that powers a star (see box on page 31). From theoretical models of stars, astronomers calculate that the cutoff point is 0.08 solar mass, the point at which the main sequence terminates. The masses of the smallest stars are 0.1 solar mass.

The light from the faintest stars is indeed feeble, but the stars make up for it by having incredibly long lives. The lifetime of any star — counted to the point at which it exhausts its hydrogen fuel and begins to evolve off the main sequence — depends upon the amount of hydrogen available in the hot core divided by the rate at which it is used. After a star's main sequence life, the time spent evolving toward death is relatively short. The Sun originally had enough hydrogen to last for 10 billion years. The ages of meteorites show that it has gone through about half that interval. For an 0.8 solar mass star, the projected lifetime is up to about 13 to 15 billion years, which is the age of the Galaxy itself. No smaller star has yet had time to evolve off the main sequence. Down at the bottom of the main sequence, a star will live for several trillion years, trading the fame and glory of great luminosity for an extraordinarily long life.

Stars That Throw Tantrums

So far, the lives of the faintest stars look quiet and predictable, if not even boring. But a large number of these stars harbor a secret. Let's take as an example the double star Kruger 60. The fainter star, at class M4, is normally 1.4 magnitudes fainter than its M3 companion. But occasionally the star, also designated DO Cephei, brightens ferociously, more than doubling its luminosity. This is typical of what astronomers call flare stars, remarkably common objects. Of the 14 most studied nearby dwarfs, nine produce flares. Even Proxima Centauri belongs to the crowd. With a few K dwarf exceptions, they are confined to class M and become more common as we descend the main sequence, at least down to M5. The brighter ones are accessible in backyard telescopes and if you are patient, would provide an entertaining evening at the eyepiece.

Consider a typical flare on the star called Gliese 867A in Aquarius, an M5 star 27 light-years away. In the near-ultraviolet, the star jumps by about 0.4 magnitude in the span of a few seconds, then takes several minutes to settle back to near, but not quite, normal. A complete recovery takes several hours. Some flares, like those of EQ Pegasi (M6, 21 light-years distant), show considerable sub-flaring or even a dip in brightness before the flare occurs. The individual events are erratic and unpredictable. A star may exhibit a tiny spark of only a few hundredths of a magnitude and then pop an enormous firecracker of a magnitude or more. The flares can occur frequently. Little microflares can occur a few times per hour, but we might wait for 100 hours to catch a big one — and then bag two in a row. These enormously energetic impulses are not confined to visible light, either. Astronomers observe such bursts in the radio, in the energetic ultraviolet, and even in the very high energy x-ray part of the spectrum.

Astronomers observe similar processes in other red dwarfs, as much as 100 times more energetic than those in EQ Pegasi. Instead of being a local phenomenon, as it is in the Sun, the magnetic fields and flares involve the whole star. Clearly life on an orbiting planet would be terrifying if not impossible. Imagine M-

Do Brown Dwarfs Exist?

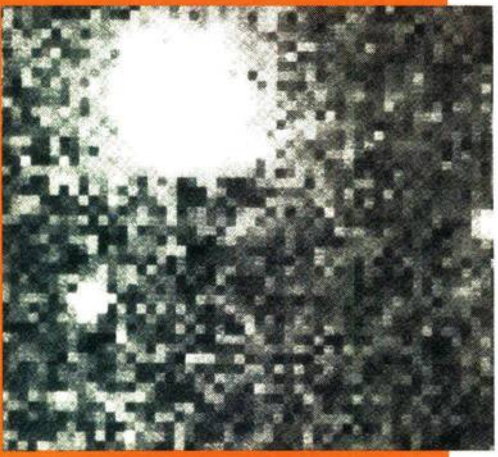
Failed stars with too little mass to ignite nuclear fires — so-called brown dwarfs — ought to exist. According to theory, they could account for a large part of the "missing mass" of galaxies. However, in close binary systems — places where astronomers should be able to detect them — none have been found.

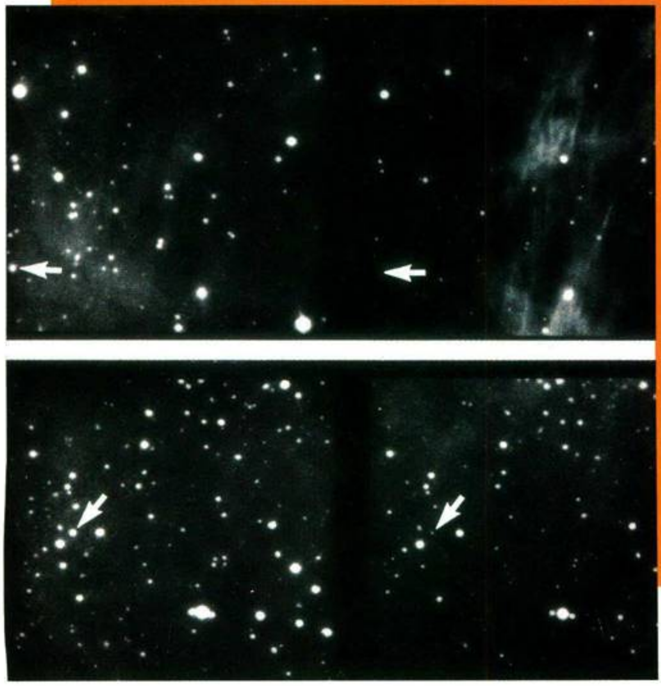
If the companions to T Tauri (right) are brown dwarfs, they would have only 10 times the mass of Jupiter.

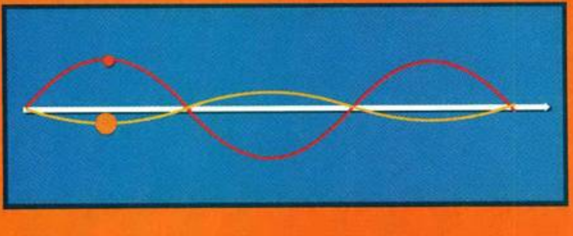
The gravitational influence of a brown dwarf on a red dwarf should be visible as a wobble in the star's proper motion (right, center).

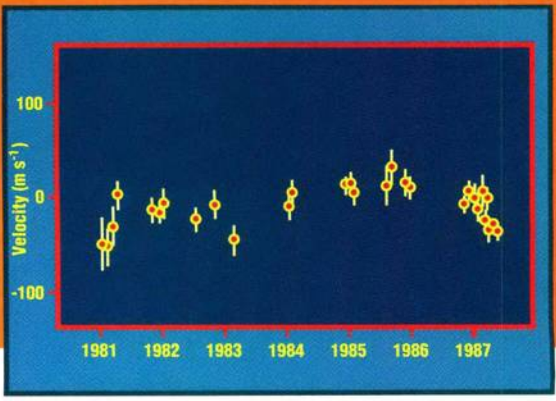
The radial velocity of Epsilon Eridani (bottom right) changes enough to indicate a planetary companion, or perhaps a brown dwarf.

Comparison pairs of photos (below) of two fields in the Pleiades cluster show infrared-bright brown dwarf candidates. In each pair, the left frame gives the infrared view, the right the view in yellow light.









dwarf bathing on the beach and having your star suddenly — with no warning at all — become 10 times brighter. The Einstein observatory revealed a steady stream of x rays coming from some M dwarfs. Because x rays are a product of the solar corona, we have direct evidence that the dim stars also have coronas. Moreover, a subset of flare stars called BY Draconis stars vary by several tenths of a magnitude. Astronomers believe this fluctuation is caused by starspots that rotate in and out of the field of view. What we see down near the end of the main sequence is a repeat performance of solar behavior, yet on a grand scale.

Below the Bottom — Brown Dwarfs

Beneath 0.08 solar mass there can be no stars, no stable, self-luminous spheres of gas that shine by thermonuclear fusion. What happens below this critical value, down under the end of the main sequence? And why might we care? Examining the gravitational effects of our Galaxy and of countless others shows that there is much more mass — perhaps 10 times more — than astronomers can account for in stars and interstellar gas and dust. Therefore, we have to find this "missing mass" somewhere else. All sorts of things have been proposed, from weird subatomic particles to black holes. One possibility might be huge numbers of dim stars that have not yet been accounted for. Even though objects below 0.08 solar mass do not stably burn hydrogen, they might exist, and should glow for a time after they form as a result of gravitational contraction and the temporary fusion of their small amount of initial deuterium. Then, like evolved white dwarfs, they cool and start to disappear. These faint, failed stars are called brown dwarfs. Although none are known to exist, searching for brown dwarfs as an explanation for the missing mass is a hot topic in astronomy.

To solve or help to solve the missing mass problem, we would like to find huge numbers of brown dwarfs. (Because they are individually nonmassive, brown dwarfs would have to exist in huge numbers to make a large contribution toward the missing mass.) There are several different ways in which astronomers look for brown dwarfs. If we could find a cool, deeply red object that has a luminosity below the end of the main sequence, then we would have found a brown dwarf. There are plenty of candidates. For example, a few years ago speckle interferometry led people to believe the star VB 8 had a faint companion. But under further scrutiny the companion disappeared — a false alarm. More recently, such dim stars have been found associated with the Pleiades and with young T Tauri variables that populate star-forming regions of space. But here, uncertainties in the stars' distances and luminosities prevent any definite conclusions.

A more rewarding method might be to examine main sequence stars for motions induced by the gravity of dim or even invisible companions. There are two ways to do this. First, we can carefully watch a star's proper motion over a period of years or even decades to see if it deviates from a straight line. For example, if a visible star has an unseen component, the star will in time appear to oscillate back and forth around its companion as it plunges through space. We know the observed star's mass from its luminosity and can infer some kind of mass limit to any companion by how much it is deflected. If it's under 0.08 solar mass, astronomers will know they've located a substellar object. The M dwarfs are the best targets because they are low in mass and easily influenced by a companion. But so far the effort has not panned out.

A more sensible approach is to monitor the radial velocities of stars, which are the movements along our line of sight. Radial velocities are easily measured by Doppler shifts in a star's spectrum and can be determined to great accuracy. An orbiting companion would shift the star first toward and then away from us, and from the velocity shifts we could infer something about the companion's mass. This research has demonstrated some solid results in that no brown dwarfs have been found. If they exist, brown dwarfs appear to be relatively rare.

But the case is not closed. If the brown dwarfs are as numerous as they appear to be in clusters and star forming regions, then there could be quite a few of them. But if they are as sparse as they seem to be in binaries, then there are hardly any at all. So at present astronomers have a major problem in interpreting brown dwarf candidates. Perhaps these failed stars are found only in certain regions of space and do not form in pairs. Whatever the case turns out to be, it seems likely that we will have to look elsewhere for the missing mass — brown dwarfs alone won't do it.

Although brown dwarfs won't solve the missing mass problem, they might offer some interesting clues in other areas. The radial velocity technique used to search for brown dwarfs may have met with success at

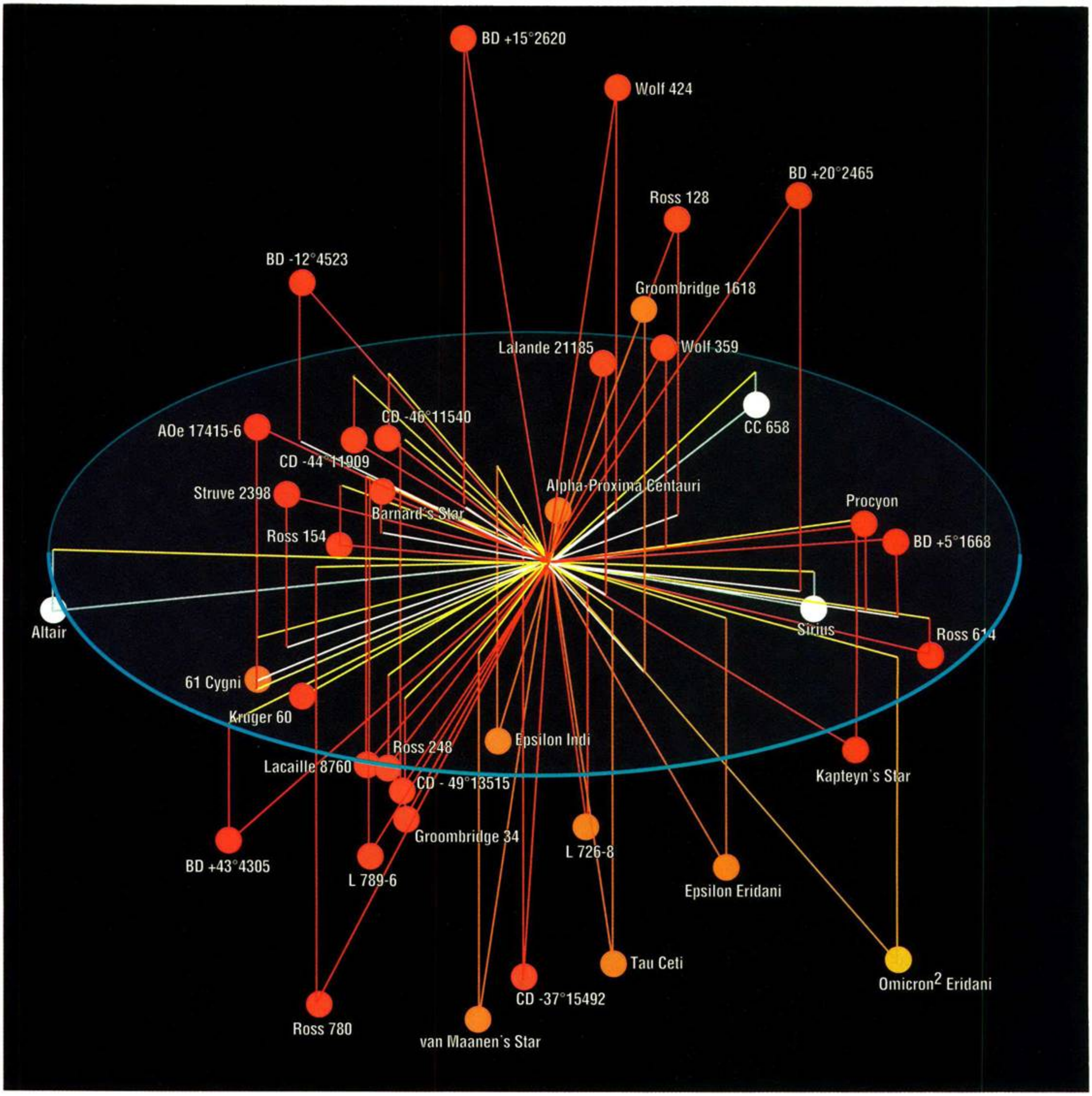
Inside the Faintest Stars

How do the faintest stars convert mass into energy? How do they keep their nuclear fires burning at such a slow rate and for such a long time? The energy of the Sun and all other main sequence stars cooler than spectral types F0 to F2 is generated mostly by the proton-proton reaction. This converts four atoms of hydrogen (H) into one of helium (He). Here's how the process works:

$$\mathbf{{}^{1}H + {}^{1}H \rightarrow {}^{2}H + \gamma + \nu}$$
$$\mathbf{{}^{2}H + {}^{1}H \rightarrow {}^{3}He + \gamma}$$
$$\mathbf{{}^{3}He + {}^{3}He \rightarrow {}^{4}He + 2({}^{1}H) + \gamma}$$

The numerical superscripts refer to atomic mass (or isotope). The helium atom is 0.7 percent lighter than the four hydrogen atoms taken together. The lost mass is converted into energy by the production of gamma rays (γ) and neutrinos (ν). This process is governed by the famed equation $E = Mc^2$. Because the speed of light (c) is so great, a very large amount of energy can be created from a small amount of mass: one gram of matter converted completely into energy could light a billion standard light bulbs for an hour.

The initial reaction produces a positron, a positive electron that is a form of antimatter. This particle encounters an electron, and the two annihilate one another and generate the energy. For stars having spectral types hotter than F0, a different chain called the carbon cycle uses carbon as a nuclear catalyst to create helium out of hydrogen.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PLOTTING THE NEAREST STARS shows clearly that the majority are red dwarfs. Although the faintest stars are small and dim, and quietly live out their lives, they outnumber all other stars and they burn their fuel conservatively so that they will outlive all more massive stars by billions of years.

finding planetlike objects. Several stars seem to show evidence of back-and-forth deflection by bodies with masses a few times that of Jupiter. The best cases are Epsilon Eridani, a K2 dwarf with a tiny companion that seems to have between 1 and 5 Jovian masses, and Gamma Cephei, a K1 giant or subgiant orbited by a body only twice Jupiter's bulk. Since there is a distinct gap of no companions between about 10 or 20 Jupiter masses and the 0.08 stellar limit, astronomers surmise they have found the extreme upper mass for planets. A wonderful area of research is opening up. We're learning where the stars stop and the planets begin and how large the gap is between the two. And we're learning the answers to these fundamental questions because of the faintest stars. Perhaps the ordinary folks are the best kind after all. □

James B. Kaler is professor of astronomy at the University of Illinois in Champaign-Urbana. His last article was "The Brightest Stars in the Galaxy" (May 1991 issue).

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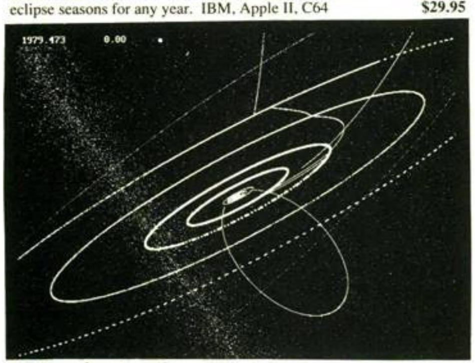

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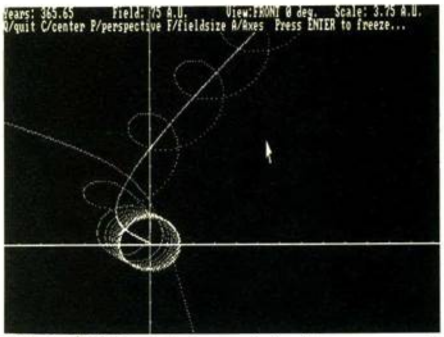

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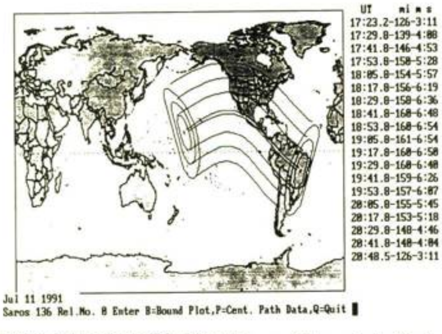

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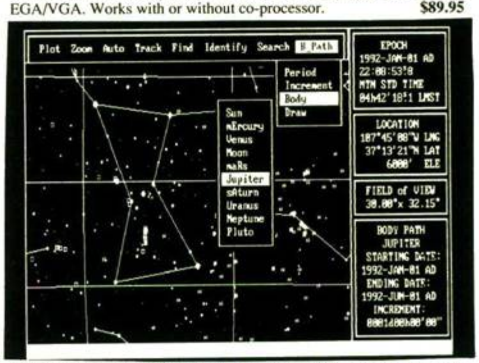

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The archaeologist is separated from ancient civilizations by an immensity of time. From scattered ruins and pottery shards, the archaeologist recreates a long-forgotten society. The astronomer, on the other hand, is separated from stars and galaxies by an enormity of space. From shards of starlight, the astronomer recreates worlds at the edge of the universe.

Yet when it comes to extracting some measure of empathy for their objects of study, it is the archaeologist who, by far, has the greater advantage. The dark, rich loam of earth gets under the fingernails of the archaeologist as she digs. Inch by inch, she uncovers the silent artifacts that once belonged to living people. Beneath the rubble of 30 centuries, daylight once again falls on the scattered ramparts and towers of Troy. Footsteps echo again in the courtyards where Priam and Helen once walked. Amid the dust and debris, a pottery flask appears that was once molded gracefully by human hands and adorned with human symbols. The archaeologist gingerly lifts it from its resting place and instantly makes contact with the labors of a ghostly ancestor. This ancestor dreamed, had aspirations, shed tears over the loss of loved ones, suffered from familiar ailments, and found beauty in the world much as we do.

The pottery and adornments of our ancestors scarcely differ from those we use today; the translated writings of ancient peoples often read like words taken from our morning newspaper. Their lives were not so different from our own — lives played out under the same stars and constellations we see every clear night.

As an astronomer I explore a different domain — the alien and inhuman starscapes that fill space. There are no artifacts here in which I can see my ancestors reflected or from which I can extract a scintilla of humanity. I work in a realm circumscribed in the sky by constellations whose networks of lines and angles reach out into space like an archaeologist's reference grid. But there are no Parthenons, Stonehenges, or Angkor Wats here to admire on a dark night. The seven sisters of the Pleiades, diadems of sublime stellar beauty though they might be, are a poor substitute for the humanity of their mythical namesakes. I cannot feel in my hands the fluffy textures of nebulae nor experience the warm rays of distant suns beating upon my face.

The labors of archaeologists can be crated up and displayed in museums for all to see. For me, only the occasional victories of thought or discovery or perhaps a brief stint at an isolated observatory serve as markers of my efforts. Obscure journals, not the display cases in a museum, record the advances in knowledge that an astronomer makes in a lifetime.

VIEWS

Archaeologists and astronomers, among all scientists, are kindred spirits whose work encompasses the two great extremes of our human limitations: time and space.

by Sten Odenwald

When I look up at the night sky, all the details I have worked so hard to fathom by day are washed away. Gone are the Great Red Spot on Jupiter and the 10,000-year-old stars struggling to be born in Orion's womb. The canvas is wiped clean. All I see are myriad points of starlight against the blackness of space, slowly turning to the west. Great galaxies of stars become mere smudges of light at the limits of human vision. This is the common reality that all humans share, the reality that poets and philosophers of past ages have pondered and artfully described, a reality which for much of humanity is completely untouched by any astronomical knowledge.

For most people, astronomy remains an unfathomable pursuit. Unlike the rich, human world brought to us by archaeologists, there is nothing about the experience of stargazing onto which we can hang familiar nouns or adjectives. The infinite depths of space that stretch out before us remain tauntingly mysterious to both astronomer and layman alike.

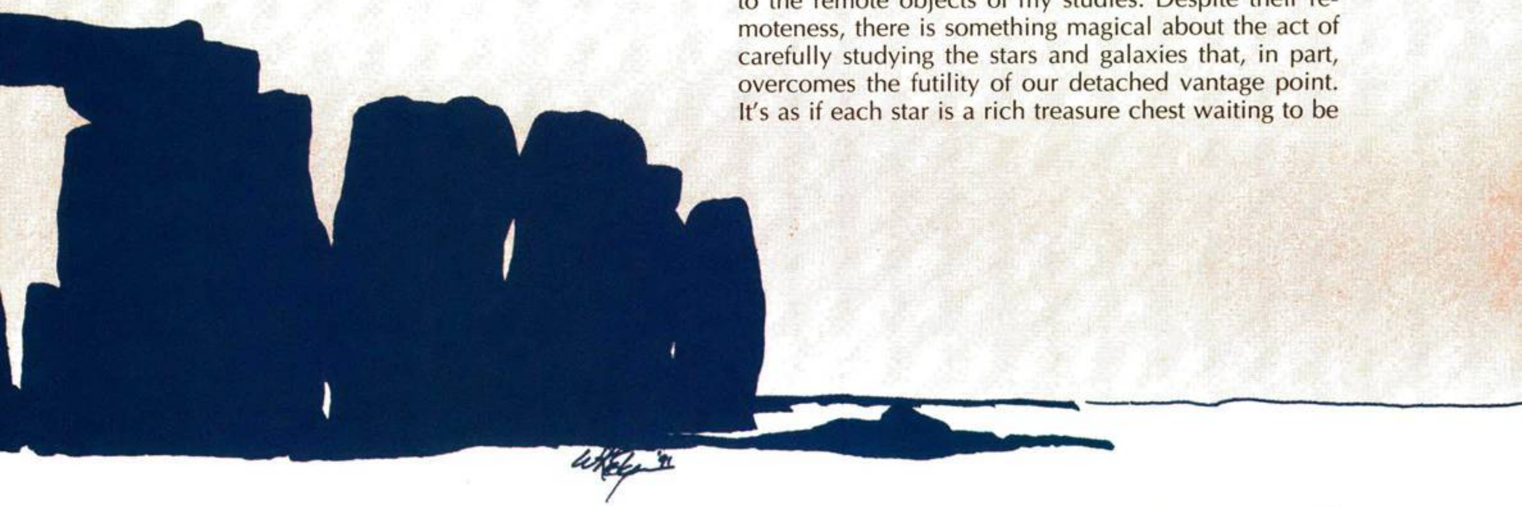
I know that the eye alone can offer but a pale reflection of the true character and richness of the night sky. The Milky Way's soft glow barely hints at its true grandeur when revealed with the help of a pair of binoculars, let alone with the instruments to dissect starlight that are at my disposal as a professional astronomer.

From the comfort of my office, I probe and measure the destinies of stars playing out their lives a thousand light-years away. Other astronomers create mathematical models of distant galaxies torn asunder by collisions with their neighbors. Scattered, hard-won data, linked together by a framework of rules by which Nature operates provide the rich fodder for our speculations. But the things we have learned have become strangely divorced from a perceptible world; our knowledge becomes mere symbols and numbers on a page. We feel a brief triumph when our symbols mesh like the teeth of a gear with an observation of some distant phenomenon. We debate endlessly over whether a supernova will leave behind a neutron star or a black hole or whether quantum field fluctuations begat the galaxies that are strewn through the universe.

But aside from an occasional meteorite and hard-won samples of moon rocks, we never have a direct personal experience of the universe as a physical entity. Like unrequited lovers, astronomers are condemned to admire the universe from afar.

Yet we still attempt to explore the universe. What is this curious dimension to our life that by day allows us to go about the mechanics of living in a world circumscribed by the tangible barriers of cityscapes, yet by night frees us to gaze upon the implacable depths of the larger universe from which we are so removed?

As an astronomer I feel an undeniable attraction to the remote objects of my studies. Despite their remoteness, there is something magical about the act of carefully studying the stars and galaxies that, in part, overcomes the futility of our detached vantage point. It's as if each star is a rich treasure chest waiting to be



opened, like an untouched cache of artifacts awaiting the archaeologist's trowels.

In a catalogue we can select one star at random: SAO 130703. It is a faint, Sun-like star in the constellation Eridanus. It has never been carefully studied by an astronomer save during the long-ago 20 seconds in which Annie Cannon at Harvard Observatory scrutinized its spectral smear on a photographic plate. The vast majority of stars in the sky are like this: distant, faint, anonymous — the orphans of astronomical research. Perhaps in the future, SAO 130703 will become an important object of study. For all any of us know today, it may be the nearest solar system to our own harboring intelligent beings. Its worlds may be among the most beautiful in the Milky Way.

While looking at the sky, I twist the dial on my radio and listen to the babble of voices and programs that drift in and out of radio focus. Voices upon voices, some bright, some dim, just like stars in the sky. Between stations hisses the rising and falling of static from millions of dancing electrons inside the radio's circuitry — the voice of the cosmic fireball that fills the dark tracts of space between the stars.

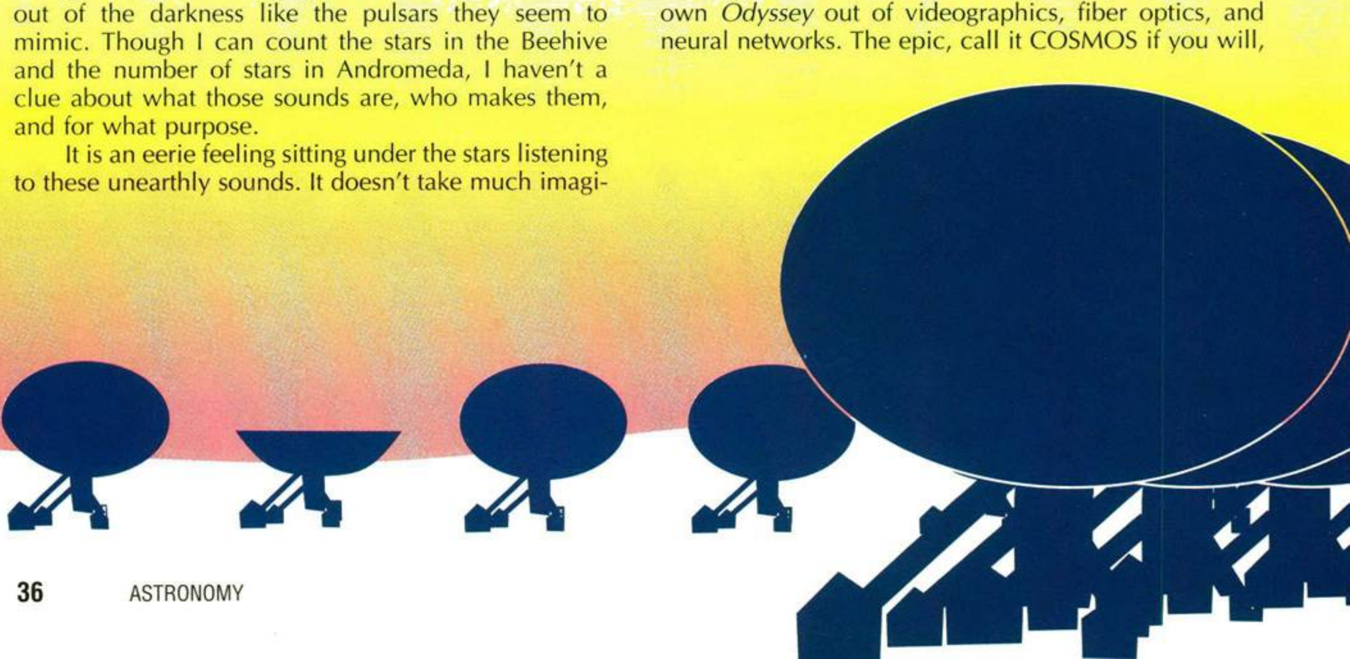
Occasionally I stumble upon inhuman sounds, strange rhythmic rumblings that warble at me from out of the darkness like the pulsars they seem to mimic. Though I can count the stars in the Beehive and the number of stars in Andromeda, I haven't a clue about what those sounds are, who makes them, and for what purpose.

It is an eerie feeling sitting under the stars listening to these unearthly sounds. It doesn't take much imagination to think I am tuning in the patter of interstellar commerce — perhaps Vega VI's transmission on quantum philosophy or the plaintive automatic signals from some long-vanished civilization out beyond Cygnus.

Of course, all this is just imagination. It is what we must resort to in order to "experience" the universe. Still, our lack of knowledge only heightens our sense of wonder about the richness of the detail hidden in the world around us. But if only there were some means to make this feeling less abstract and our journeys to the stars less dependent on flights of imagination. If only we could put all we know about the universe into a form everyone could see, feel, and touch, something as tangible as the artifacts unearthed by the archaeologist.

The laws of physics don't allow too many options for exploring the universe without at the same time demanding great sacrifice of human life and material. Will it be mechanical feet that first step forth onto the surfaces of distant worlds in space? Will robot eyes attached to silicon brains be the first to see sunsets on these worlds? Will the expense of space exploration ultimately become a ruinous burden on any society that attempts it?

Perhaps imitating the epic poems of past ages, astronomers and engineers will someday create their own *Odyssey* out of videographics, fiber optics, and neural networks. The epic, call it COSMOS if you will,



Like unrequited lovers, astronomers are condemned to admire the universe from afar.

would contain all that we know about our physical world, but it would not be a verbal tale passed on by word of mouth. It would be a complete multi-sensory experience allowing the human participant to visit any point in space and time as an incorporeal consciousness. All of our senses would be stimulated in ways only now dimly conceivable, allowing us to experience the universe directly. What does the Great Nebula in Orion taste like? Does the Sun sound like a church bell? What would it feel like to run barefoot across Saturn's rings?

This great cosmic epic might allow us to experience the tragedies and joys of the universe as an archaeologist studies the tragedies and joys of a people destroyed by conquest or natural disaster. We know that space is filled with the silent screams of dying stars. Yet we feel little compassion for the death of a star. We never mourn the certain destruction visited on a billion planets in the core of a Seyfert galaxy. As humans removed in space and time from what we study, we can only for the time being mark the passing of stars and planets with empty lifeless figures and tables and then move on to the next spectacle. By providing an experience as lifelike as physical reality, COSMOS would bridge this gap, making us all participants in the workings of the universe.

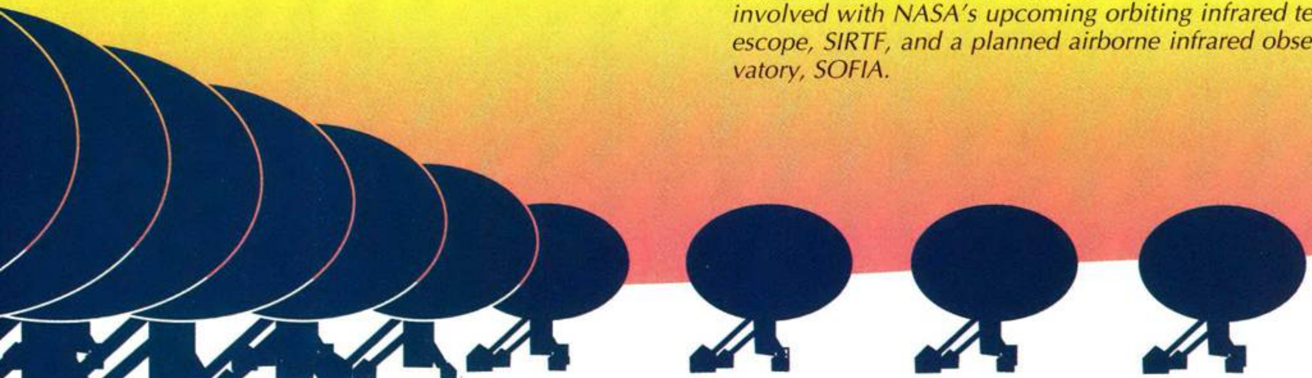
As our knowledge advances, so would the details blended into COSMOS. The epic compilation would force us to redefine our concept of perception. Unlike space travel, which is an experience limited to only a few dozen humans, reality simulations such as our hypothetical COSMOS would broaden our experience of the physical universe, making it accessible to all of humanity, not just a few thousand astronomers.

These are the thoughts and visions that come to me during idle moments at a mountaintop observatory. Gazing at the starry sky, I take part in imaginary journeys through space. But my journeys are all inner visual experiences driven by considerable mental gymnastics. They lack the tactile excitement and sensory experiences that a real exploration would provide. I long for a COSMOS epic of the future. I envy the archaeologist of today and her ability to touch the evidence of *her* explorations.

As a child in California, I watched as the Milky Way drifted silently overhead and set in the west. I wondered about the vastness of it all, what it would be like to stand on Mars or gaze at the Milky Way from outside its star spangled disk.

Last summer I watched the Milky Way with my niece. It was the same galaxy above me and the same stars. She asked me the same questions I had pondered in my youth, and I tried to answer them with all the precision and imagination my science could provide. As an astronomer, I had come a great distance in my mental travels through the spaces above me. I knew so much more about the universe. Yet I realized how little of it I had experienced. ☐

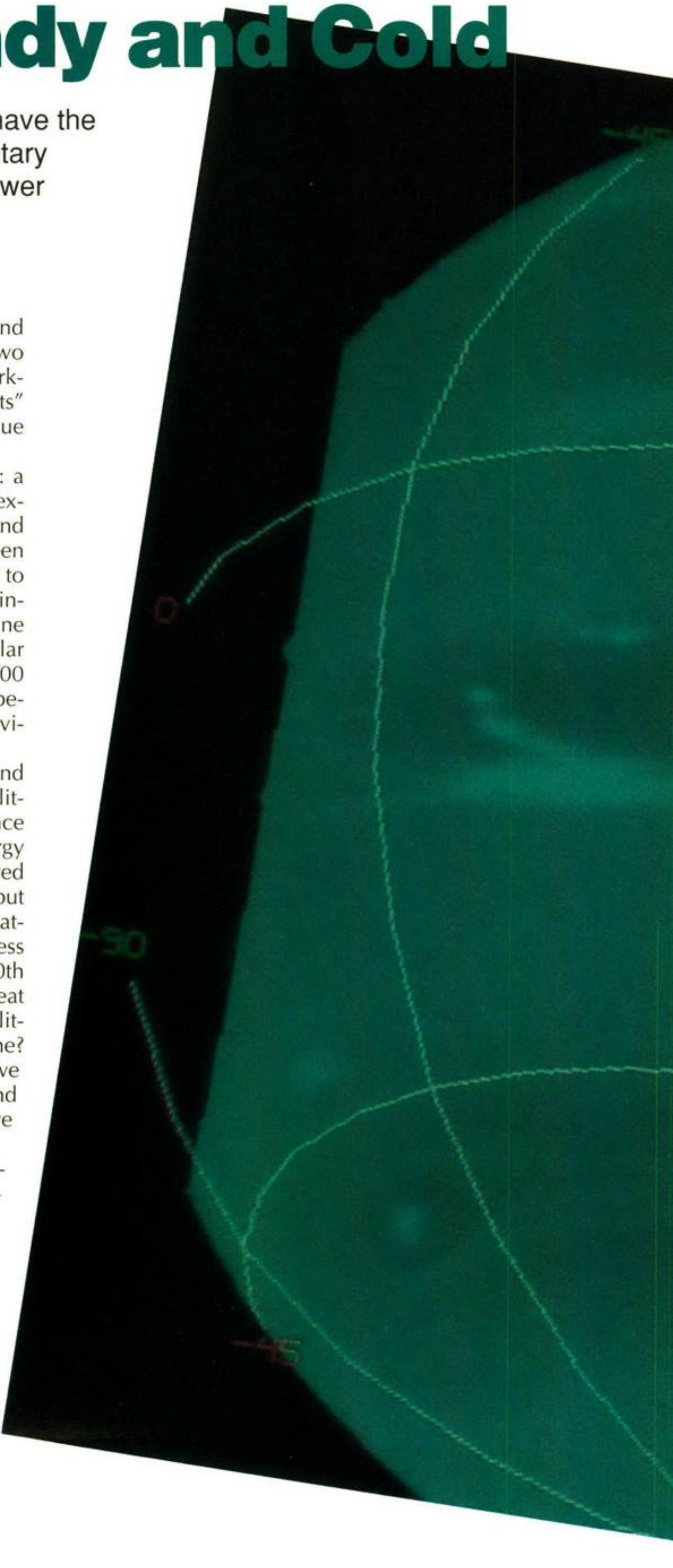
Sten Odenwald is an infrared astronomer at the Naval Research Laboratory in Washington, D.C. He is also involved with NASA's upcoming orbiting infrared telescope, SIRTF, and a planned airborne infrared observatory, SOFIA.



Neptune's Weather Forecast
Cloudy, Windy and Cold

Why does a planet so far from the Sun have the fastest winds in the solar system? Planetary astronomers think they've found the answer deep within Neptune.

by Sanjay S. Limaye



Planets that have atmospheres have weather, and Neptune is no exception. In the almost two years since Voyager revealed Neptune's remarkable atmospheric features, planetary "meteorologists" like myself have been trying to understand this blue world's weather.

Neptune is a strange environment for weather: a place where, after encountering a bland Uranus, we expected to find little — and where we were surprised and rewarded by a richness of phenomena that have been challenging to understand. Voyager found Neptune to be a planet with active cloud forms and features reminscent of those on Jupiter and even Earth. Neptune turned out to be the windiest planet in the entire solar system — with "breezes" reaching speeds of over 2,100 kilometers per hour. These findings were a surprise because Neptune's clouds and winds didn't fit what previous planetary encounters had led us to expect.

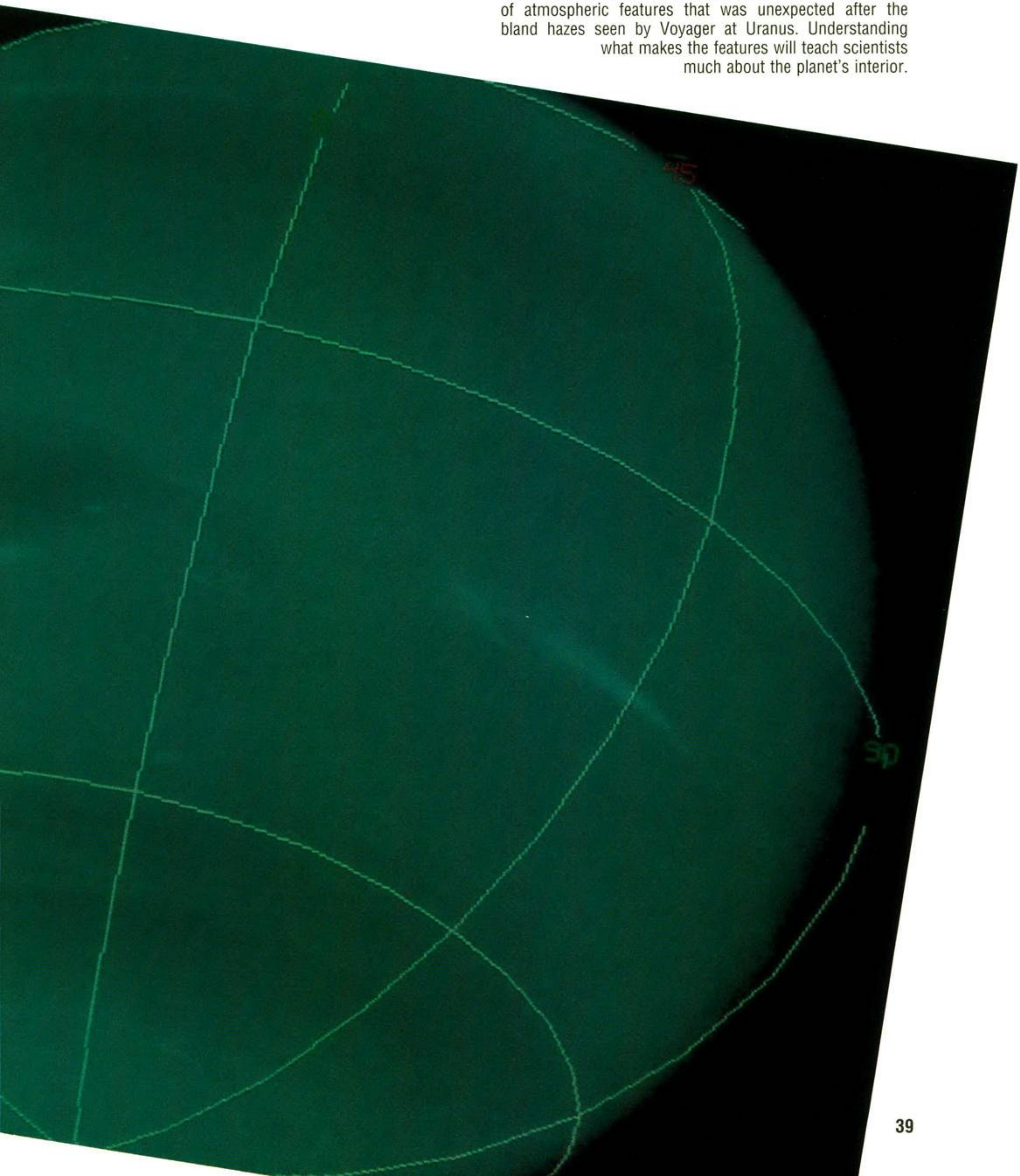
On Earth, solar heating drives the weather and winds (heat flowing up from the interior contributes little), and solar energy is abundant at Earth's distance from the Sun. But farther from the Sun, as solar energy dwindles, internal heat matters more. Voyager showed that Jupiter, which receives 1/27th Earth's sunlight but which has abundant internal heat, has a highly active atmosphere. Saturn, with 1/90th our solar energy and less internal heat, is quieter. Uranus, which gets 1/370th Earth's solar energy and has no detectable internal heat flow, displays a bland, deeply hazy atmosphere with little variation over the short or long term. And Neptune? It orbits where it receives only 1/900th the energy we do. With less than half the solar energy at Uranus and only a small internal heat source, Neptune could have been blander than bland.

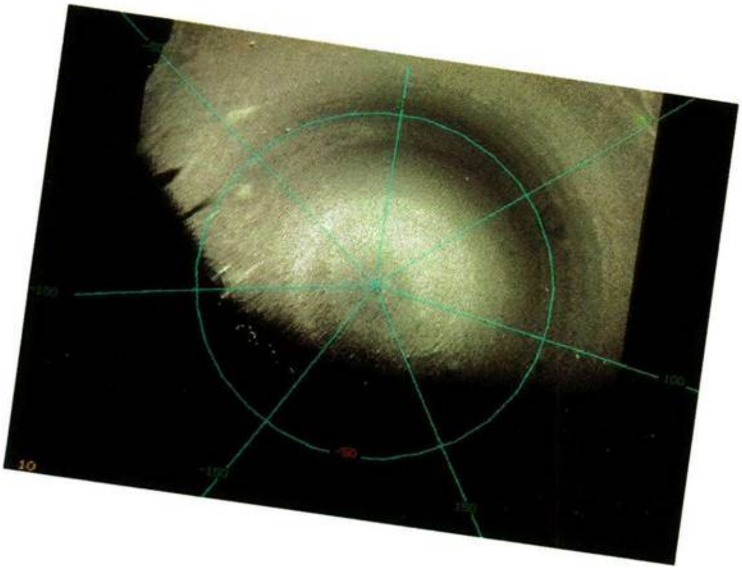
Yet it wasn't. And over the months since the encounter, scientists have been studying the images — making movie loops to show Neptune's changing clouds, measuring their motions, and theorizing about their origin and the processes that drive them.

Clouds of Neptune

Voyager's biggest surprise was that Neptune even *has* clouds and storms. The first atmospheric feature seen in early Voyager images turned out to be one of the largest cloud systems not just on Neptune but in the whole solar system! Soon, by analogy with Jupiter's Great Red

THE BLUE-GREEN SURPRISE, Neptune offered a richness of atmospheric features that was unexpected after the bland hazes seen by Voyager at Uranus. Understanding what makes the features will teach scientists much about the planet's interior.





A COMPUTER'S EYE VIEW shows the south pole of Neptune. For unknown reasons, cloud features in this region have short lifetimes, often lasting only a few hours before disappearing as quickly as they appear.

Spot, this feature in Neptune's southern hemisphere was dubbed the Great Dark Spot. Comparable in size to the Red Spot, Neptune's Dark Spot is even centered at roughly the same latitude as the Red Spot is on Jupiter. And like the Red Spot, it appears to be rotating counter-clockwise, just as any high-pressure system in Earth's southern hemisphere does. (These similarities to the Red Spot give us hope we'll eventually understand its existence.)

But the Dark Spot has peculiarities too. First, it appears to vary more in size than the Red Spot. Second, Voyager movies show that while the Dark Spot retains an elliptical shape, it oscillates oddly. When the Dark Spot's north-south extent is shortest, the Spot stretches farthest east-west, and vice-versa. Third, the Red Spot is bounded by an easterly jet to the north and a westerly jet to the south, so it "rolls" between two opposing flows of wind like a ball bearing. But the Dark Spot lies wholly within a rapid westward flow and small clouds appear to move over it in some images. Finally, just as the origins of the Red Spot are unknown, those of the Dark Spot are equally mysterious, although it has probably lasted a few years at least and is very likely a semipermanent feature.

Some clues to the origins of Neptune's features may lie in its strong preference for particular types of cloud at particular latitudes. For instance, at the south pole Voyager spotted a tiny bright speck of cloud lying almost exactly at 90° south. Surrounded by bands of dark and light haze, this feature is unique to Neptune.

At 54° south, Neptune has a second dark spot called the Dark Spot 2, or just DS2. Similar in appearance to the Great Dark Spot and also rotating counterclockwise, DS2 obeys one rule violated by its larger relative: DS2's center lies in a latitude where the winds to its south blow east while those to the north blow west. However, DS2 appears to be an obstacle in an otherwise uniform river of wind: the flow is gently deflected around the spot, much like a small pebble wrapped in a big spool of ribbon.

On Earth the equator is loosely marked by a band of cumulus clouds paralleling the equator (although not always straddling it). On Neptune we see a similar kind of cloud right on the equator, particularly in images made in the methane band. This methane-rich cloud appears tied to the global circulation, as are Earth's equatorial clouds.

At 30° north, Voyager saw white clouds that look like jet contrails — long, narrow, and straight. Such streamer clouds straddle the Dark Spot near its midsection in one or two strings and also occur at 30° north. High-resolution images of the clouds show that they cast shadows on the main cloud deck below. From these, Voyager scientists estimate that the clouds drift 75 to 100 kilometers above the main cloud deck. At mid-southern latitudes there occur similar but much shorter clouds.

The Great Dark Spot has a feature called the southern companion, which appears linked to an intriguing kind of rippling wave cloud. On Earth these occur where a mountain range smoothly lifts a jet of air and gives its downstream flow a gentle ripple. But on Neptune what provides the uplift? One possibility is that the Dark Spot is a column of warm rising gas that forms a kind of "bump" in the Neptunian atmosphere.

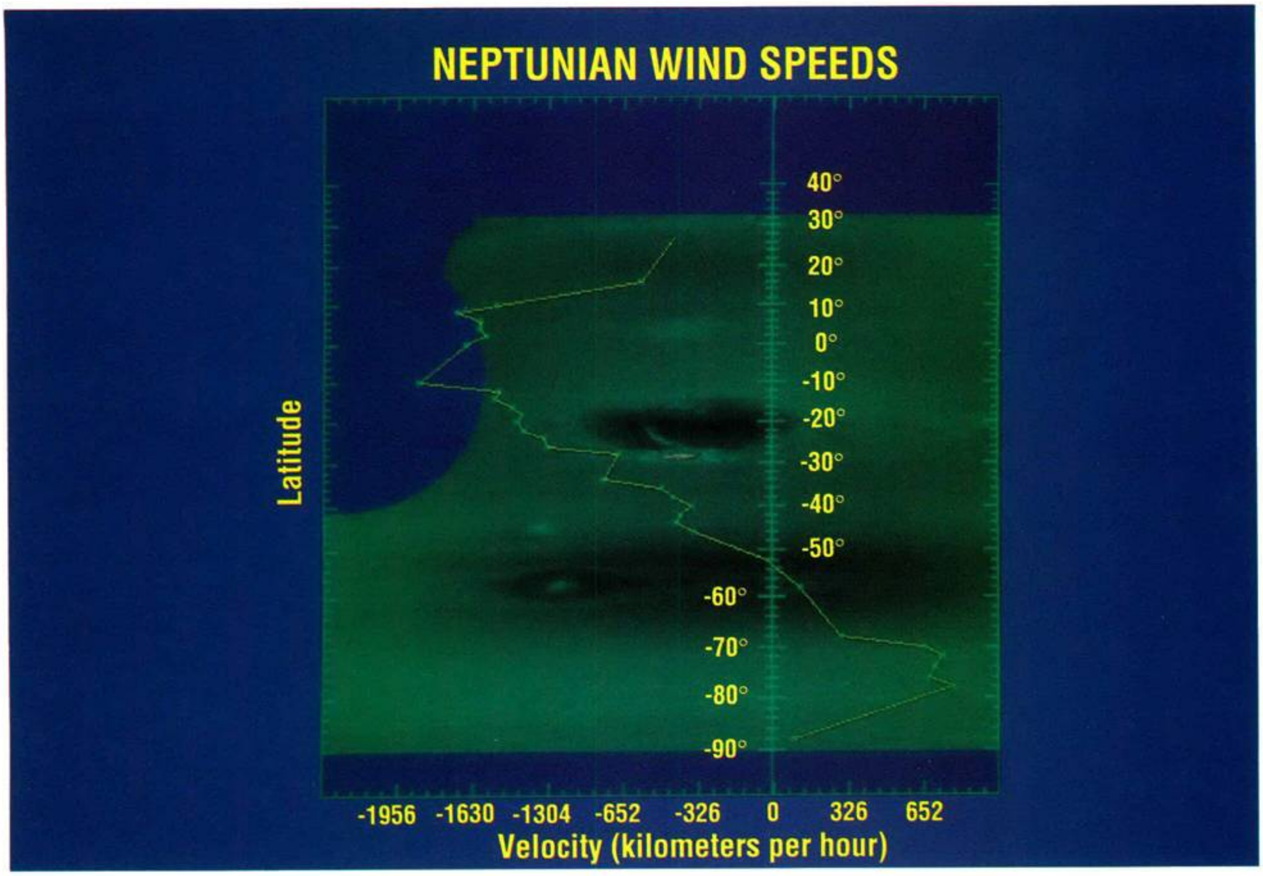
Here Today, Gone Tomorrow?

Another clue to the source of energy behind the Neptunian cloud features is their lifetime. In planetary meteorology, size generally correlates with longevity. Jupiter's enormous Red Spot has been seen telescopically for 300 years at least. Elsewhere on Jupiter (and on Saturn) clouds smaller than Neptune's Dark Spot persist for at least several planet rotations. But Neptune is quite different: with the exception of the Great Dark Spot and DS2, its clouds evolve very rapidly. For example, features around the south pole cannot be followed for more than a few hours, let alone one Neptunian day. But what makes the clouds form and disappear so quickly is unknown.

Looking at larger-scale features, Neptune joins Jupiter and Saturn in having a strongly banded atmosphere, which sets them apart from Uranus. Scientists believe the rapid rotation of these planets and the relatively small differences in temperature from the equator to the poles are key reasons for the bands to exist. Earth and Mars, by contrast, have relatively large equator-to-pole temperature differences and long rotation periods; their thin atmospheres have turbulent, somewhat disorganized banding. But what controls the number of bands and widths? These are basic questions that have no answers as yet.

Winds of Neptune

Whatever the origins of the cloud features, tracking the velocity of individual clouds provides the easiest way to measure Neptune's winds. The method assumes, however, that small clouds will flow with the prevailing winds and indicate both direction and speed. Unfortunately, how much a given cloud shares in the local wind speed is not known very well. (In hurricanes, for example, clouds in the spiral bands may exceed 100 miles per hour but the storm as a whole may crawl at only 20 mph.) Used with caution, however, cloud motions determined from spacecraft images remain useful in mapping global winds.



WINDS SURE BLOW FAST, WAY OUT THERE! Neptune turned out to have the fastest winds in the solar system.

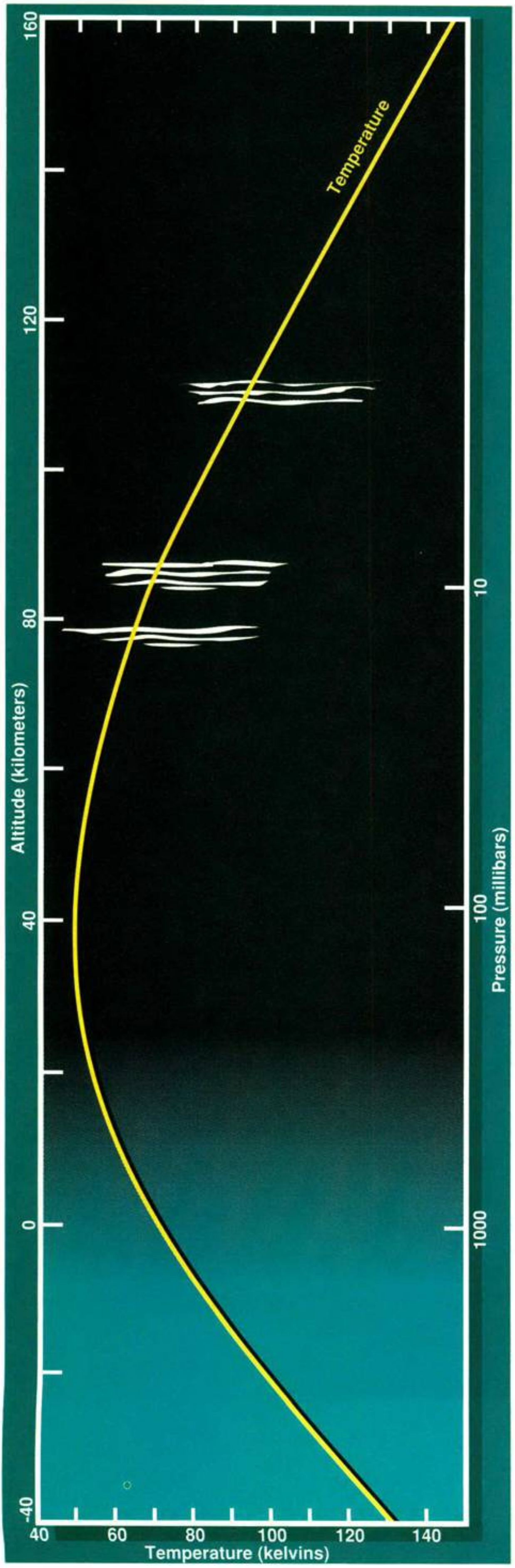
Other methods can yield wind speeds indirectly and let us check the speeds given by cloud motions. Two such Voyager experiments were the infrared interferometer and spectrometer (IRIS) and the radio occultation experiment. The IRIS results told us about winds by means of a meteorological relationship between the horizontal variation of temperature and variations of wind with altitude. The radio occultation experiment obtained wind speeds indirectly by the variable bending of the radio beam as it traversed the atmosphere on its way to Earth.

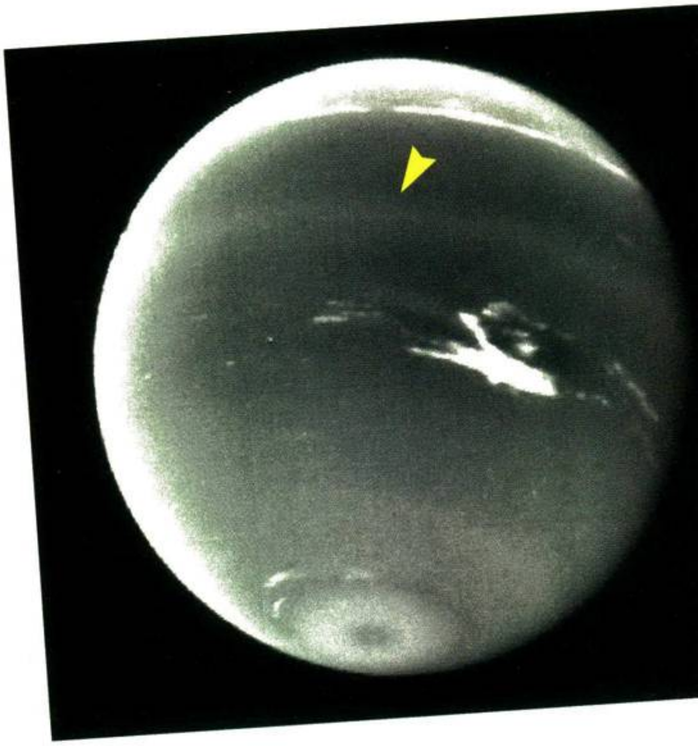
Of course, the idea of wind carries with it the idea that it is moving relative to something. On Earth we measure winds relative to the surface — that is, using a reference frame that rotates with the solid Earth. For Neptune or any other gaseous planet, planetary meteorologists have chosen as a reference frame the time the deep interior takes to make one complete rotation. Since this region is hidden from view, we measure this "day" by the rotation rate of the planet's radio emission.

Long before Voyager, scientists suspected that Neptune had winds. Michael Belton and his associates at Kitt Peak National Observatory analyzed photometric observations made by Dale Cruikshank and Robert Brown in the summer of 1980; these gave "rotation periods" of 17.73, 18.29, and 18.56 hours. Since the planet's actual rotation wouldn't vary like that, the results pointed to wind-driven bright cloud features. Later Heidi Hammel of the Jet Propulsion Laboratory studied ground-based methane band images of Neptune and found additional evidence of atmospheric motions.

Nevertheless, the length of Neptune's day — the basic frame of reference — remained unknown even as the spacecraft was nearing the actual encounter. The problem was and is more than academic because models of the interior structure require a rotation rate of about 15 to 16 hours. The difference between this period and the

STREAKS OF CIRRUS-LIKE clouds drift 75 to 100 kilometers above the main cloud deck of Neptune.





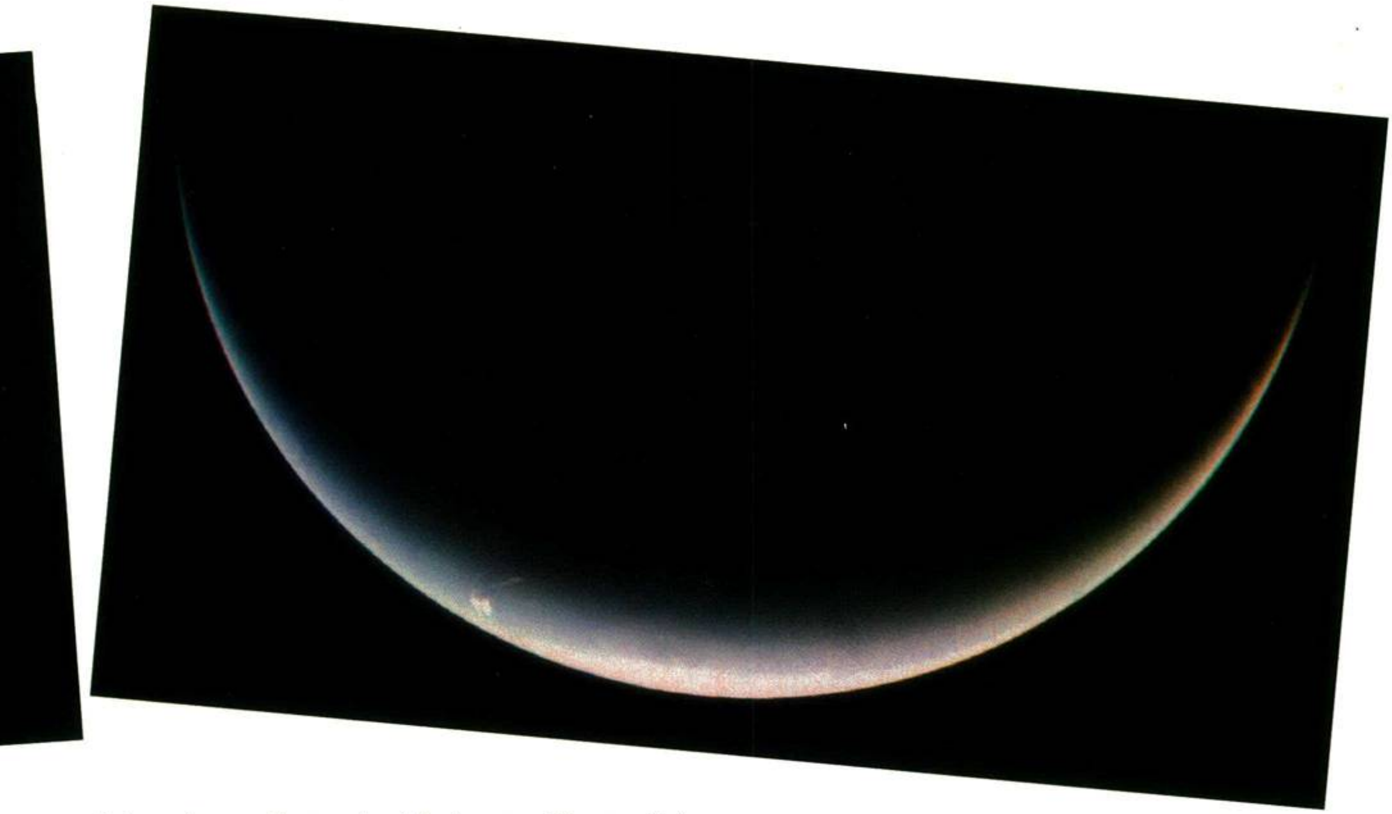
STREAKY AEROSOL CLOUDS FORM HIGH in Neptune's atmosphere (left) when ultraviolet sunlight breaks up ammonia and methane. Seen in the light of methane, a faint band marks Neptune's equator (arrow, above).

18-hour periods derived by Mike Belton from photometry pointed to very fast winds indeed. In the end, Voyager didn't pin down the length of Neptune's day until just before closest approach. From early results on the in-bound leg, many scientists predicted that the radio-emission period would be 18.3 hours, close to the rotation period for the Dark Spot.

Once the radio emissions were fully analyzed, however, scientists discovered the Dark Spot rotates more slowly than the deep interior by more than two hours every rotation. Thus it is actually drifting westward at a high rate. Translated into velocity, the measurement shows the Dark Spot lies where the wind blows westward at more than 2,000 kilometers per hour. (The diagram on page 41 shows the wind velocities at several latitudes, drawn from work by Lawrence Sromovsky and me.)

How can the Dark Spot — a fluid structure larger than Earth — do this? This was a question that gave quite a few sleepless nights to Verner Suomi, a scientist at the University of Wisconsin and a member of the imaging science team. In a recent paper published in the journal *Science* he and his colleagues suggest that the Dark Spot (and the rest of the atmosphere at cloud level in low latitudes) lags behind the internal rotation because their motions originate in the deep circulation within Neptune.

How does deep circulation link to a westward drift at the surface? Angular momentum is the key. If any material, such as a bubble of hot gas, rose up through Neptune's atmosphere, it would retain its original angular momentum. Brought to the surface, which lies farther from the planet's spin axis, the bubble would rotate more slowly, much as whirling ice



EVENING HAZES ARE BLUE (left side), morning ones are red. During the 9-hour Neptunian night, some unknown process alters the atmospheric aerosols or methane.

skaters slow as they extend their arms. The result is that the bubble would lag behind the surface rotation and appear to drift westward.

But does Neptune have rising parcels of gas? The answer clearly is yes. Measurements show the planet loses more heat than it receives from the Sun and so its surface is colder than its interior. In cooling, Neptune's atmosphere rises to the top and because Neptune is largely gaseous, it is quietly "boiling" like a giant saucepan. As upwelling parcels of Neptune's atmosphere rise from the deep interior, they lag in rotation speed. From the point of view of the visible surface, they move rapidly westward with reference to the deep interior rotation rate.

Neptune's wind profile is similar to that of Uranus: in the equatorial latitudes, winds blow against the sense of rotation and *with* it in the higher latitudes. The main difference is that the crossover point lies at lower latitudes on Uranus. According to models developed in our work, this implies that the zone of convection — the region of rising gas — extends to greater depths on Neptune. This agrees with the observation that Uranus loses less heat than Neptune, although they are about the same size.

Toward the Unknown Regions

Neptune's windy weather promises to help planetary meteorologists look inside the planet and puzzle out its heat "engine." On Earth, the equator is cooled and the poles warmed by the transport of heat within the atmosphere-ocean system and by water changing its phase from solid to liquid to vapor and back again. On the gaseous planets, however, the heat exchange occurs entirely within their deep atmosphere and with little change of phase.

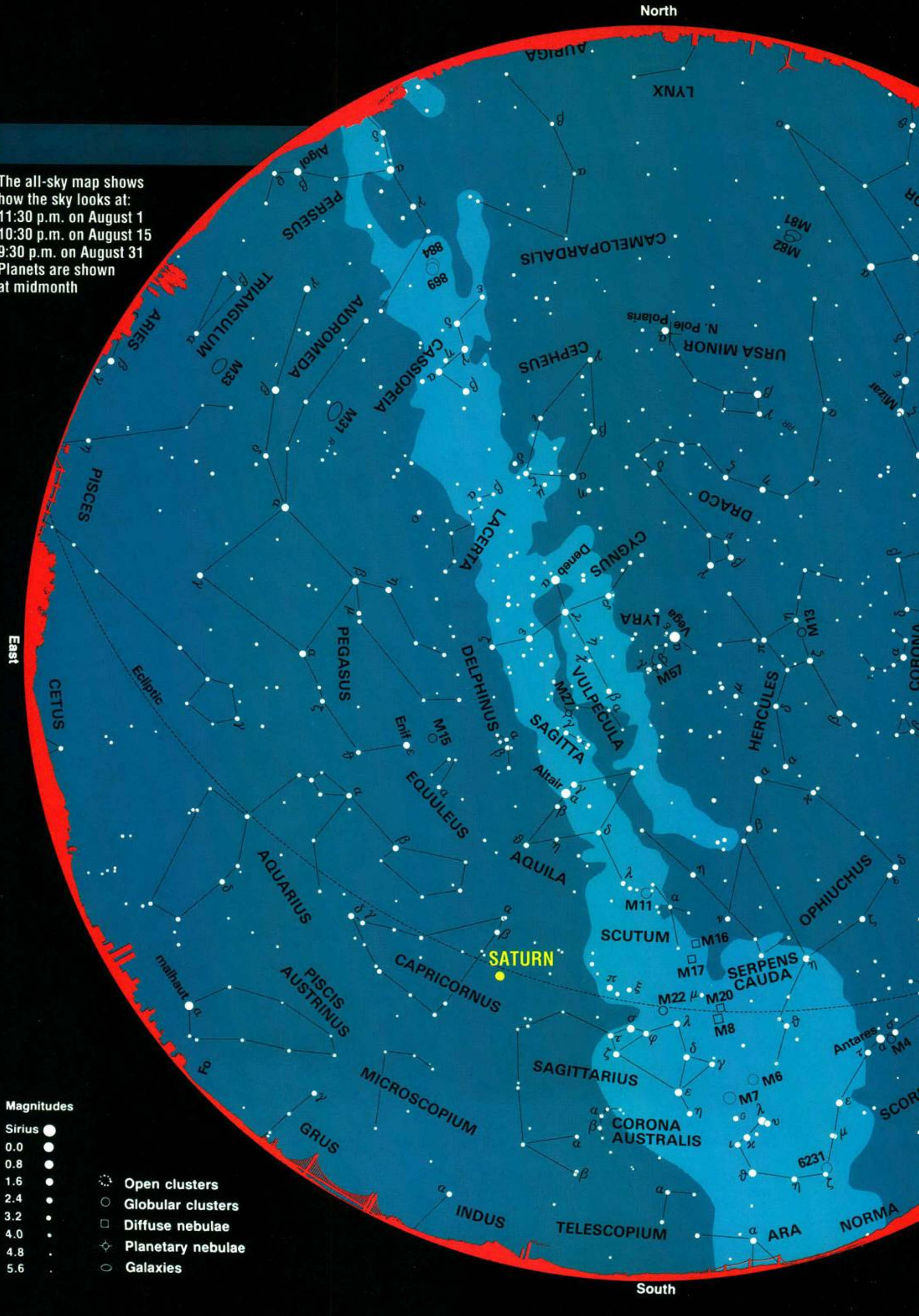
We have learned that even when the heat absorbed from the Sun is significant, the tilt of a planet's axis is not particularly important. For example, both Venus and Jupiter have negligible tilts, so their poles receive little sunlight — yet their poles have almost the same temperature as their equator. Uranus provides an extreme example: despite having one of its hemispheres in darkness for half its 84-year orbit, the temperatures at the dark pole and the sunlit one are nearly the same. Neptune, with a moderate axial tilt, is the same. Yet while its temperature differences are small in an absolute sense, they are nevertheless relatively significant because Neptune's temperatures are very low overall.

Surprisingly, Voyager's IRIS measurements found no trace of the Dark Spot. This might indicate the Dark Spot is covered with a haze that blocks infrared emission. It could also indicate that the Spot extends deep within Neptune to a place where the rotation period is shorter. Thus, the visible Dark Spot and its infrared counterpart may have different longitudes.

We have by no means finished analyzing the Voyager data, and much more remains to be learned from future work. Over its 12-year journey through the solar system, Voyager has made crucial contributions to our understanding of the weather on the gas giants. This era of continual discovery will remain unmatched in human history for a long time. We are so close to the events that it is difficult to place a value on this knowledge, but whatever scientists of the future may come to think about the project, I feel very fortunate to have been part of it. ☐

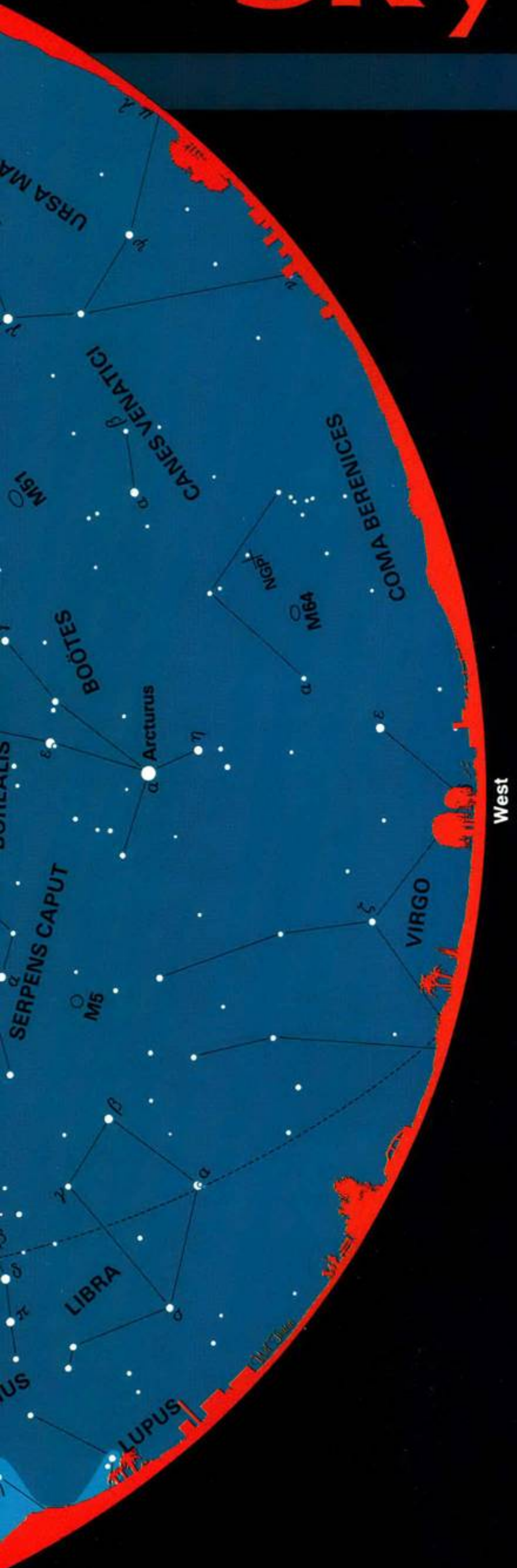
Sanjay S. Limaye is a planetary scientist at the University of Wisconsin. He has worked on the Mariner 10 mission and on Voyager. Recently, he has been engaged in a project to measure the environmental impact of the Kuwaiti oil-field fires.

The all-sky map shows how the sky looks at:
11:30 p.m. on August 1
10:30 p.m. on August 15
9:30 p.m. on August 31
Planets are shown at midmonth


North
AURIGA
LYNX
Algol
PERSEUS
CAMELOPARDALIS
M81
M82
884
869
TRIANGULUM
ARIES
ANDROMEDA
CASSIOPEIA
M33
M31
N. Pole Polaris
URSA MINOR
CEPHEUS
Mizar
PISCES
LACERTA
DRACO
CYGNUS
Deneb
LYRA
Vega
M57
M13
CORONA
East
Ecliptic
CETUS
PEGASUS
DELPHINUS
VULPECULA
M27
SAGITTA
HERCULES
Enif
M15
EQUULEUS
Altair
AQUILA
AQUARIUS
M11
OPHIUCHUS
SCUTUM
M16
M17
SERPENS CAUDA
SATURN
CAPRICORNUS
PISCIS AUSTRINUS
Fomalhaut
M22
M20
M8
Antares
M4
SAGITTARIUS
M6
M7
MICROSCOPIUM
SCORPIUS
CORONA AUSTRALIS
GRUS
6231
INDUS
TELESCOPIUM
ARA
NORMA
South
Magnitudes
Sirius
0.0
0.8
1.6
2.4
3.2
4.0
4.8
5.6
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

Sky Almanac

August 1991



PERSEIDS PEAK ON AUGUST 12/13

Hundreds of fast-moving and colorful meteors will shoot across the moonless sky on the night of August 12/13, when the annual Perseid meteor shower reaches its peak. Expect to see 50 or more meteors per hour in the prime observing hours after midnight.

SATURN SENSATIONAL THIS SUMMER

The ringed planet appears prominent in the southeast at mid-evening throughout August, as it shines at magnitude 0.2 from the constellation Capricornus. Observers with telescopes will enjoy the view of the 18"-diameter planet encircled by a ring system that spans 42".

COMET MACHHOLZ RETURNS

As Comet Machholz sweeps by Earth at the beginning of August, it appears low in the west-northwest as night falls. With a telescope you can expect to see a small, diffuse patch of light glowing softly at about 10th magnitude.

MERCURY AND VENUS TOGETHER

The two inner planets lie close to one another in the evening sky as the month begins. The two are closest on the evening of August 6, when they are separated by just 2° and can be found with binoculars just above the western horizon 15 to 30 minutes after sunset.

Calendar of Events

3 Last Quarter Moon is at 7:25 a.m. EDT

7 Mercury passes 2° north of Venus, 2 a.m. EDT

8 The Moon is at perigee (223,756 miles from Earth), 2:12 p.m. EDT

9 New Moon is at 10:28 p.m. EDT

11 The Moon passes 3° north of Venus, 3 a.m. EDT

The Moon passes 0.6° north of Mercury, 4 a.m. EDT

12 Perseid meteor shower peaks

14 Asteroid Dembowska is at opposition

17 First Quarter Moon is at 1:01 a.m. EDT

Jupiter is in conjunction with the Sun

20 The Moon is at apogee (251,752 miles from Earth), 6:33 p.m. EDT

21 Mercury is in inferior conjunction

22 Venus is in inferior conjunction

The Moon passes 1.8° north of Saturn, 7 p.m. EDT

25 Full Moon is at 5:07 a.m. EDT

27 Asteroid Hebe is at opposition

Eye on the Sky by Deborah Byrd

A GREAT YEAR FOR THE PERSEIDS

This summer has been grand for sky-watching, and it's not over yet. In many years, the event of the summer is the Perseid meteor shower. This year, the Perseids follow on the heels of June's close gathering of planets in evening twilight and July's solar eclipse. But this meteor shower is no anticlimax. It's an event that you should be sure not to miss!

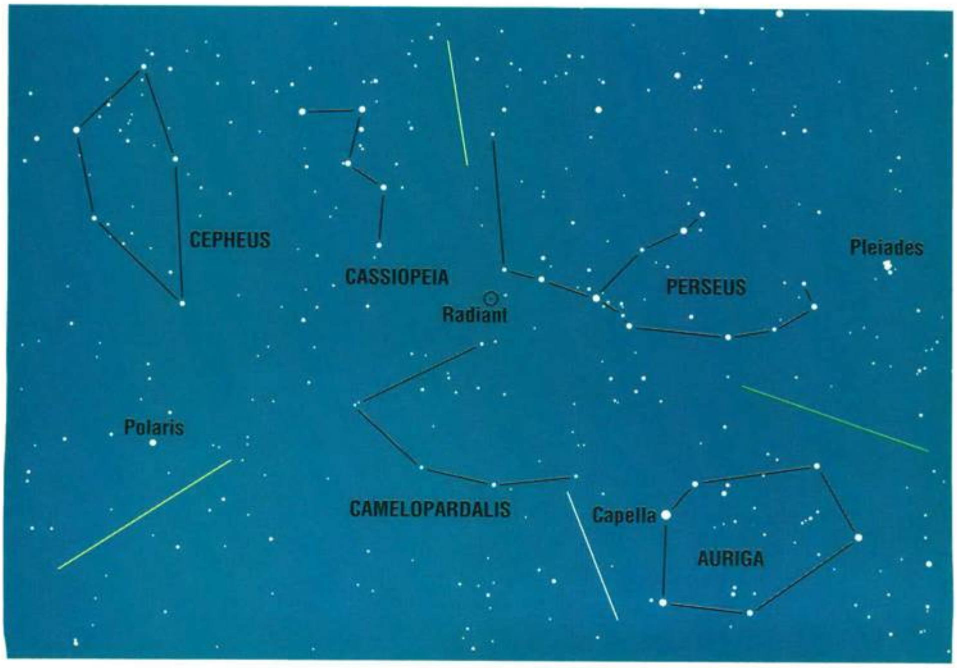
Skywatchers love the Perseid shower because it is reliably strong and takes place at a time of year when the nights are warm. The only years that aren't good for Perseid-watching are those when the Moon is up during the peak of the shower. This year, the shower peaks on the night of August 12/13, when the Moon is only three days past New. Thus the Moon is absent from the predawn sky, when the meteors are most plentiful. (For more on the Perseids, see pages 56 and 64.)

People used to call the Perseid shower the best of the year. A decade ago, the shower seemed to be building, with the meteors becoming more numerous from one year to the next. The reason seemed apparent. Meteors in annual showers originate in comets. As cometary ices sublime under the action of sunlight, they liberate tiny pieces of debris that get left behind in the comets' orbits. When a meteor shower's parent comet returns to the inner solar system, the shower often intensifies. The comet that spawned the Perseids, Comet Swift-Tuttle, had been seen from Earth only once, in 1862. Its 120-year orbit was expected to carry it back into our vicinity during the early 1980s.

But no sightings of Swift-Tuttle were made. Perhaps the comet came and went without anyone noticing. In any case, the number of meteors in the Perseid shower now seems to be declining. No matter. If you choose a site far from the city that affords a clear view of the entire sky, you won't be disappointed.

To get the most enjoyment out of the shower, bring along a lawn chair or blanket so you can recline comfortably while looking up at the sky. Plan to watch for at least an hour on the night of August 12/13, when you can expect to see 50 or more meteors per hour. (The numbers tend to be higher after midnight because Earth is then running head-on into the meteor stream.) Though the meteors radiate from a point in the constellation Perseus, they appear in all parts of the sky. Perseid meteors show a wide range of brightnesses and display many colors, with yellow and white being the most common. They are the closest Nature comes to shooting off fireworks. Don't miss them!

MOVING STREAKS will pepper the early morning sky on August 13 as the Perseid meteor shower reaches its peak. That morning, you can expect to see roughly 50 meteors per hour emanating from Perseus, which lies high in the northeast.

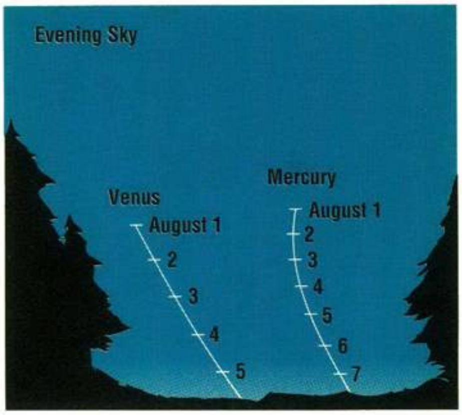


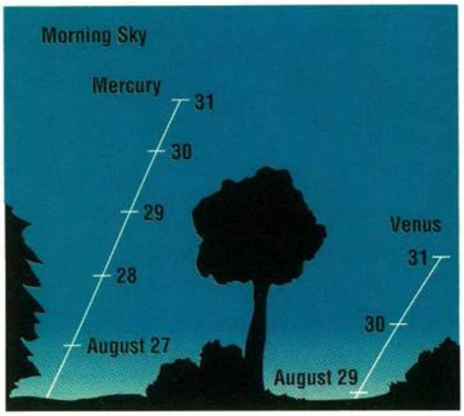
SATURN PROMINENT IN THE EVENING

The least conspicuous of the bright planets, Saturn, reached opposition late last month. Now the planet can be found in the southeast when night begins. The golden-colored planet makes a low arc across the southern sky throughout the night and sets shortly before dawn.

This year, August is probably the best month for gazing at Saturn in the evening hours. Because Earth recently passed between Saturn and the Sun, the planet is now nearly at its brightest. It shines at magnitude 0.2 among the background stars of Capricornus. If you stare at Saturn for long, you'll probably notice that its light appears steady. Now contrast Saturn's serene glow with the glittering light of a bright star. What you're seeing is one of the few differences between stars and planets that can be discerned with the naked eye — stars twinkle and planets shine steadily.

Strange as it may seem, the naked-eye appearance of Saturn depends strongly on something that can be seen only with a telescope — the planet's glorious ring system. Because they cover such a large area and reflect most of the sunlight that strikes them, the rings are the major factor governing the planet's brightness. In the course of Saturn's 30-year orbit around the Sun, the ring system's inclination as seen from Earth changes constantly. The rings appear slightly less open now than they did a year ago and Saturn looks fainter because of it. In just four more years the rings will appear edge-on and Saturn will be only about half as bright as it is now.





VENUS AND MERCURY move in unison from the evening to the morning sky this month. Look for the pair just north of due west about 30 minutes after sunset in early August (left) and a bit north of due east 30 minutes before sunrise in late August (right).

AUGUST'S PLANETS

Mercury and Venus lie near each other in the western evening sky when August begins. Look for them in the twilight glow no later than about 30 minutes after sunset. You probably wouldn't notice the pair at all if Venus weren't so bright. Shining like a beacon at magnitude –4.4, Venus is more than 100 times brighter than 0.8-magnitude Mercury. You'll most likely need binoculars to spot Mercury, which lies 3° to the right of Venus on August 1.

After the first few days of August, both Venus and Mercury disappear in the Sun's glare. They pass directly between the Sun and Earth — a configuration called inferior conjunction — just one day apart. Mercury reaches inferior conjunction on August 21; Venus follows 23 hours later.

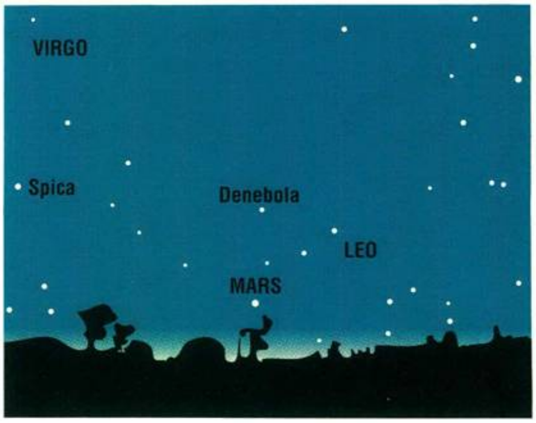
Then these two planets return to view in the eastern sky before dawn. Once again, it's the brightness of Venus that makes it possible to notice the pair. Look for them during the last two or three days of August about 30 minutes before the Sun rises, when they lie very low in the east.

Jupiter joins Venus and Mercury in the predawn sky at the end of the month. The giant planet is behind the Sun as seen from Earth, in conjunction, on August 17. By August 31, it can be seen emerging in the east, shining brightly at magnitude –1.7. Jupiter appears 10° to the left of Venus. Mercury lies between Jupiter and Venus and is somewhat higher in the twilight sky.

The only planet that remains in the western sky during evening twilight throughout August is Mars. It's there, but only barely. When the month begins, Mars stands above Venus and Mercury in the west after sunset. It's fainter than either of those planets at magnitude 1.8.

During the course of the month, Mars moves steadily eastward in front of the stars, crossing from Leo into Virgo. In this way it manages to escape the clutches of evening twilight, but it does get increasingly hard to see. By month's end, you'll probably need binoculars to locate the Red Planet.

ONE PLANET THAT REMAINS in the western evening sky after early August is Mars, which lies low in the twilight glow about 30 minutes after the Sun sets.



Saturn shines in the southeast when night begins. Just five days past opposition at the beginning of August, the ringed planet is bright and well-placed for evening viewing. Be sure to look for Saturn on the evening of August 22, when the planet lies only 2° from the waxing gibbous Moon.

THE STARRY SKY

On a late summer morning, as dawn's light creeps into the eastern sky, look in the direction of the coming sunrise for what may be a familiar shape. The legendary constellation Orion, the mighty hunter of the sky, rises in the east before dawn in late July and early August for latitudes in the United States. It's a sight worth getting up early to see.

We commonly associate Orion with the winter sky. In winter, it stands high in the south, against a backdrop of inky darkness. The constellation sinks into the evening twilight in April. According to skylore, Orion never wants to appear in the sky at the same time as the constellation Scorpius, for it was the scorpion who stung and killed Orion.

As dawn breaks this month, the dreaded scorpion has set below the western horizon. Orion returns to the sky, looming up from the eastern horizon in a way that's beautiful, chilling, and reminiscent of the passing of the seasons.

Orion is easy to recognize. For one thing, this constellation contains two of the sky's brightest stars. Ruddy Betelgeuse varies slightly in brightness, but averages magnitude 0.5. Bluish Rigel shines at magnitude 0.1. These stars are bright but, strangely enough, they're not Orion's most noticeable feature. Instead, the hunter is best known for his belt, a short straight line of three medium-bright stars.

When Orion rises before dawn, the belt stars point straight up from the horizon. Orion comes up on his side, holding his shield in front of him, ever-ready to fend off the charging bull Taurus, which rose slightly earlier into the predawn sky.

Our identification of Orion as a hunter comes from Greek and Roman times. But many other cultures have also identified this pattern of stars with a giant in the sky. Medieval Germans, for example, knew Orion as a giant called Orwandil. If you see Orion — at this time of year or any other — you'll have no trouble seeing the figure of the giant.

What's more, seeing Orion before dawn gives you a chance to see the "Moon illusion" with a constellation. The Moon illusion is a psychological effect, which causes the Moon to appear largest when it is closest to the horizon. Likewise, when Orion is near the horizon before dawn, a subtle illusion enhances our view of the hunter by magnifying the apparent distances between its stars. The result is that Orion looks bigger than ever! ☐

ORION RETURNS TO VIEW in the morning sky in early August. The bright object to the left of Orion in Dewey Vanderhoff's photo is Venus. Sirius is just poking above the horizon.

Deborah Byrd is the creator, writer, and producer of "Star Date," an independently syndicated daily radio series on commercial and public radio.

Through the Eyepiece by Rick Shaffer

THE RETURN OF COMET MACHHOLZ

Early this month you have the chance to view an unusual comet with a very strange orbit. Discovered by amateur astronomer Don Machholz in 1986, Periodic Comet Machholz travels around the Sun in a highly elongated orbit that features the smallest perihelion distance of any short-period comet — 0.13 astronomical units — and an extremely high inclination relative to the plane of the ecliptic of 60°. This high inclination means that it rarely passes near any planet and thus has a stable orbit.

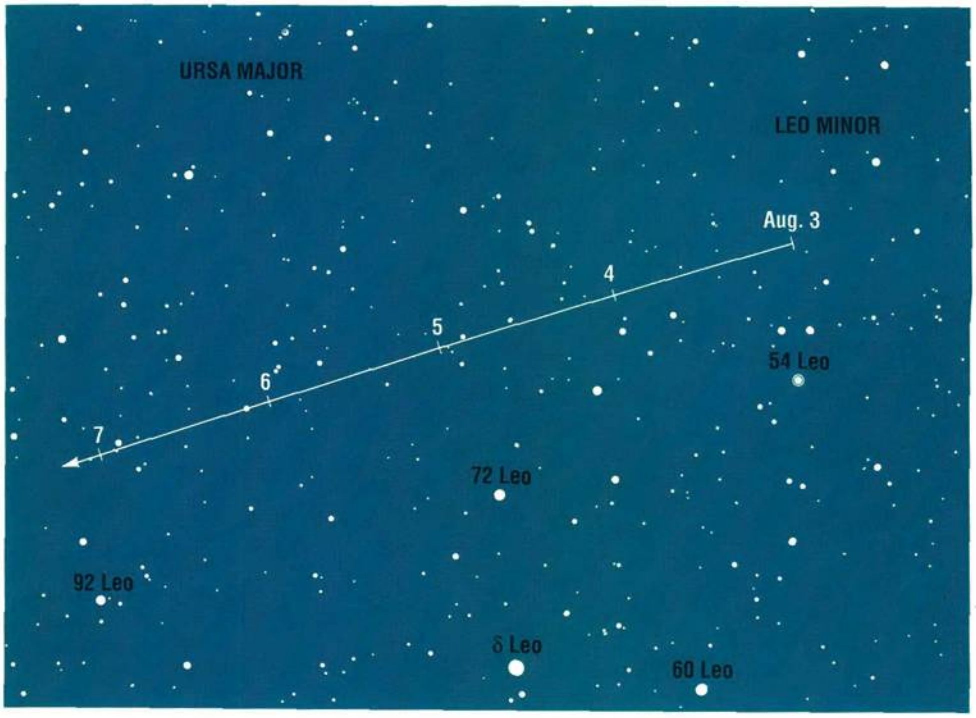
Your best view of Comet Machholz should come during the first week of August, when it becomes visible in the evening sky after perihelion. At that time Machholz is expected to shine at 9th or 10th magnitude. (Keep in mind, however, that predicting how bright a comet will become is far from an exact science.) If its behavior in 1986 is any indication, Machholz may fluctuate in brightness and display short tails that point both toward and away from the Sun.

To find Comet Machholz, you'll have to be ready to observe shortly after the Sun sets. On August 5, Machholz lies 16° above the west-northwestern horizon as nautical twilight ends. It is moving rapidly to the east at this time, which means that it climbs higher in the sky with each passing day. Unfortunately Machholz is fading as well, so you won't be able to observe it for long. Use the finder chart or table of coordinates at right to locate Machholz's position during the first week of August. Center the comet's position in your eyepiece and then bump the power up to at least 100x to be sure you don't mistake the comet for a star. A few minutes is all you'll need to detect the comet's motion relative to the stars. Averted vision will help you spot any tail that might be present. (For more details on the current Machholz apparition, see "A Puzzling Comet" on page 69.)

Why does a comet that comes so close to the Sun reach only 10th magnitude? After all, when we look at a comet what we really see is its coma, a cloud of gas and dust released from the comet as its surface is heated by sunlight. Several studies of Comet Machholz made during its 1986 apparition showed that the Sun warms only a small fraction of the comet's surface enough to become active, perhaps as little as 1 percent.

COORDINATES FOR COMET MACHHOLZ

Date	R.A. (2000)	Dec.
Aug. 1	10h31.0m	27°56'
Aug. 2	10h43.5m	27°24'
Aug. 3	10h55.7m	26°46'
Aug. 4	11h07.6m	26°04'
Aug. 5	11h19.2m	25°16'
Aug. 6	11h30.4m	24°26'
Aug. 7	11h41.3m	23°31'

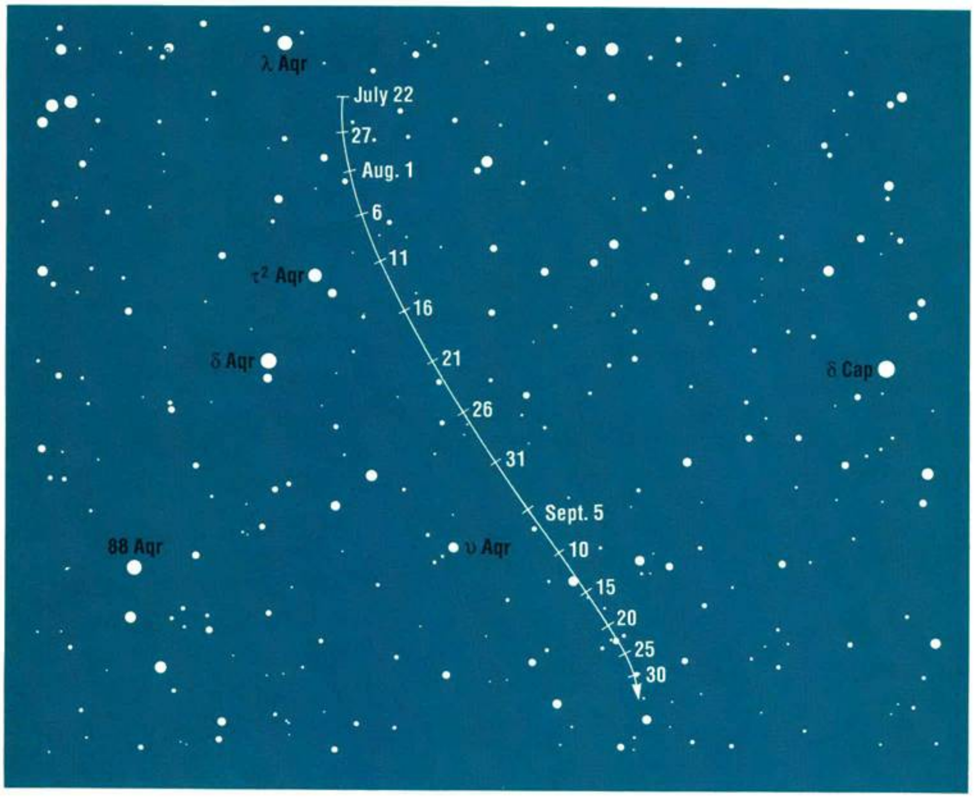


COMET MACHHOLZ ZOOMS through northern Leo during the first week of August, when the 10th-magnitude fuzzball is best-placed for observing. Machholz's positions are shown for 11 p.m. EDT (10 p.m. CDT, 9 p.m. MDT, 8 p.m. PDT).

SATURN DOMINATES THE EVENING SKY

Because Saturn reached opposition in late July, it is well-placed for telescopic viewing in August. It crosses the meridian just a bit after midnight (local daylight time) early in the month and at 10:30 p.m. at the end of the month. (For a complete guide to observing Saturn during this summer's apparition, see "Saturn, Lord of the Rings," on page 72.)

If you're blessed with a night of good seeing, what can you expect to see? Besides the subtle banding in Saturn's atmosphere and the beauty of the planet's ring system, you may be able to spot the shadow of the planet as



ASTEROID 6 HEBE shines at magnitude 7.6 when it reaches opposition in Aquarius on August 27 and remains at 8th magnitude or brighter through the end of September. Positions are shown for 11 p.m. EDT (10 p.m. CDT, 9 p.m. MDT, 8 p.m. PDT).

COORDINATES FOR HEBE

Date	R.A. (2000)	Dec.
July 22	22h46.5m	−9°01'
July 27	22h46.5m	−9°54'
Aug. 1	22h45.9m	−10°55'
Aug. 6	22h44.5m	−12°02'
Aug. 11	22h42.5m	−13°15'
Aug. 16	22h40.0m	−14°32'
Aug. 21	22h36.9m	−15°51'
Aug. 26	22h33.6m	−17°11'
Aug. 31	22h30.1m	−18°28'
Sep. 5	22h26.6m	−19°42'
Sep. 10	22h23.3m	−20°50'
Sep. 15	22h20.3m	−21°50'
Sep. 20	22h17.9m	−22°43'
Sep. 25	22h16.2m	−23°26'
Sep. 30	22h15.2m	−23°59'

it falls on the rings. Wait a minute, you say. Saturn was at opposition on July 27, so its shadow should lie almost exactly opposite our perspective in early August. That's true, but by the middle of the month, the shadow appears to be the same width as Cassini's division in the rings. So if the seeing is good enough for you to spot Cassini's division on a given night, you should have a pretty good shot at seeing the shadow to the east of the planet as well. Try viewing Saturn every clear night in August to see on which night you can first detect the shadow of the planet on its rings.

SPOTTING THE SATELLITES OF URANUS

Saturn's more distant neighbor, Uranus, offers much less visual beauty than the ringed planet. The 5.6-magnitude, blue-green world displays a featureless disk that measures only 3.7" across. But though Uranus doesn't offer beauty, it does offer a challenge that many observers find rewarding.

The challenge is in finding Uranus' two brightest moons, Titania and Oberon. Under a dark sky on nights of good seeing, owners of 8-inch or larger telescopes can spot these two 14th-magnitude points of light lying less than 1' from Uranus. To start, you need to find Uranus. That's the easy part. The planet lies about 1° due south of the star 28 Sagittarii and easily outshines the stars in its immediate vicinity. You can use the finder chart at the top of the next page to locate Uranus.

The series of diagrams below the Uranus' finder shows the positions of Titania and Oberon on six evenings in early August when the Moon is out of the sky. Use a medium-power eyepiece and zero in on the position of each of the two moons in turn, placing Uranus just outside the field of view to cut the glare from the planet. If the night boasts excellent seeing and transparency, you should see the moons. If you aren't convinced that you've found them, return the next night. If the two dots you saw the previous night have moved to keep pace with the satellites' orbital motions, you'll know you've got them. And you can count yourself among the select few who have faced the challenge of observing the moons of Uranus — and won.

TELESCOPIC PLANETS

Besides Saturn and Uranus, the planet pickings this month are rather slim. Both Mercury and Venus pass between the Sun and Earth around the middle of the month (Mercury on August 21, Venus on August 22) and thus are lost to view for most of August. However, you can see the relatively large disks and crescent shapes of the two planets at the very beginning and end of the month.

On August 1, both Mercury and Venus can be found low in the west about 30 minutes after sunset. Mercury displays a 8.8"-diameter disk that is only 34-percent illuminated. On the other hand, Venus appears 47.3" in apparent diameter and is 13-percent lit.

By August 31, both inner planets have moved into the morning sky, where they can be seen low in the east about 30 minutes before sunrise. Mercury then measures 9.1" across and is only 15-percent lit. At the same time, Venus appears 56.3" in apparent diameter and displays a razor-thin, 3-percent-lit crescent phase.

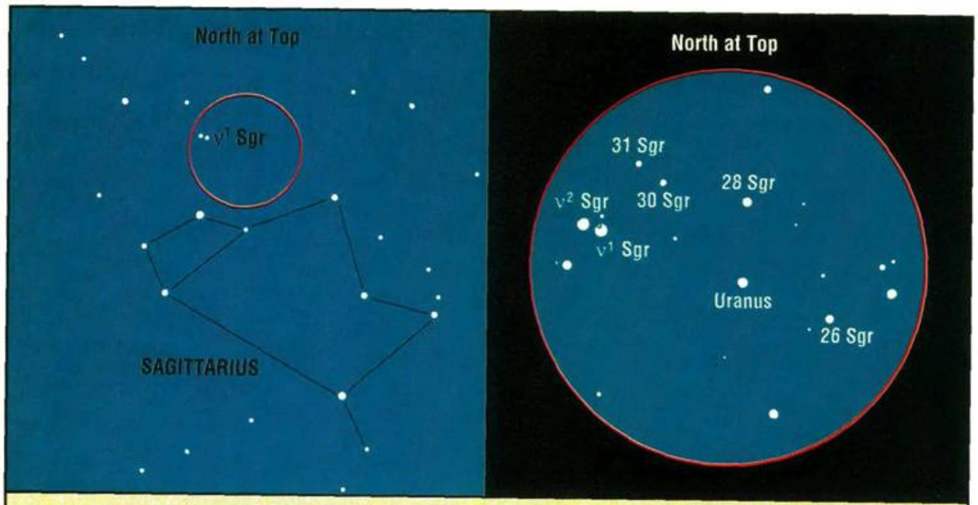
Mars is slightly easier to see than Mercury and Venus, but not by a lot. The Red Planet lies low in the west after sunset and is difficult to see against the bright twilight background. The Red Planet shows a featureless disk measuring 3.8" across and deserves only a brief look, at most.

Jupiter is in conjunction on August 17 and is essentially lost in the Sun's glare all month. It will return to the predawn sky early next month.

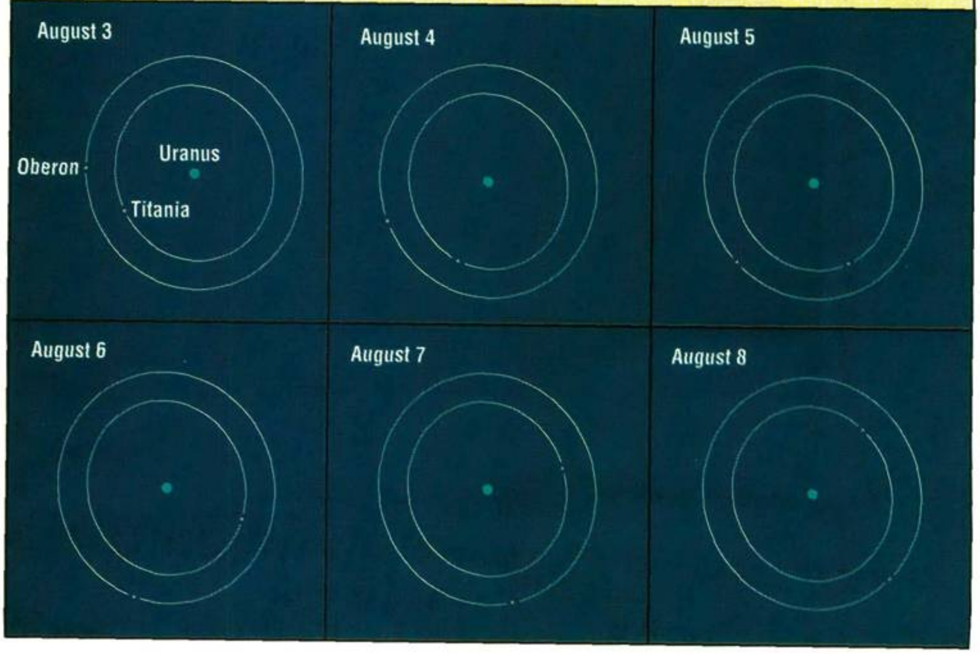
That brings us to Neptune, Uranus' neighbor in Sagittarius. Like Uranus, Neptune reached opposition in early July and is now well-placed for viewing in the evening sky. The distant planet shines at magnitude 7.9 and displays a 2.3"-diameter, blue-gray disk.

ASTEROIDS IN THE EYEPIECE

This summer has seen a string of asteroids come to opposition, and the parade continues in August. The minor planet 6 Hebe shines at magnitude 7.6 among the stars of Aquarius when it reaches opposition on August 27. Spectroscopy shows that this 200-kilometer-wide piece of rock is reddish in color, but it is too faint to show up as anything but white in your eyepiece.



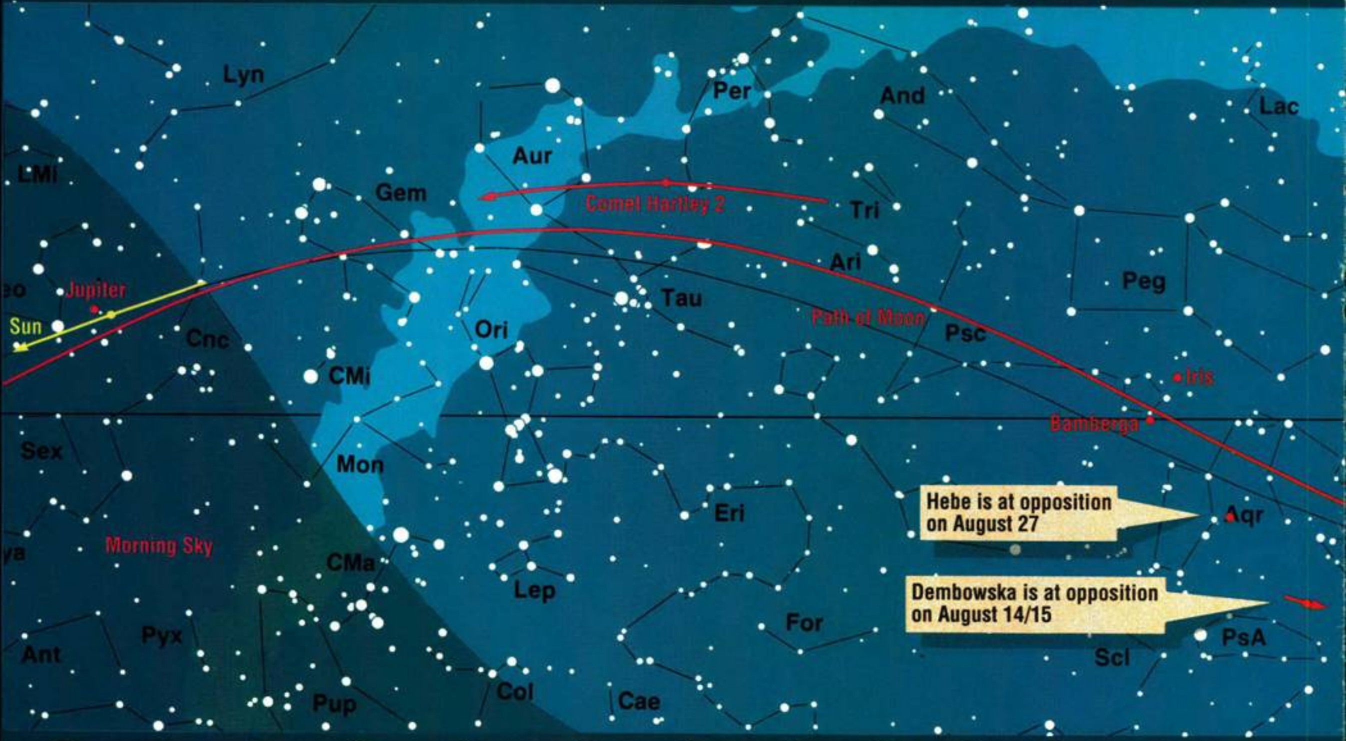
YOU CAN SEE THE MOONS OF URANUS this month with an 8-inch or larger telescope. First, find ν^1 Sgr above the Teapot asterism in Sagittarius with the naked-eye finder chart (above left); then starhop to Uranus using the 5°-wide binocular field of view (above right). The diagrams below show a telescopic view, with south at top, of Titania and Oberon's positions relative to Uranus at 11 p.m. EDT (10 p.m. CDT, 9 p.m. MDT, 8 p.m. PDT) on six nights in early August.



To locate Hebe, use the finder chart or table of coordinates on the opposite page to locate the asteroid's approximate position. The chart shows stars faint enough that you can probably identify Hebe by comparing your telescope's field of view with the map. To confirm your sighting, however, sketch or photograph the field and return to the same area a night or two later. When you look in the eyepiece and see that one of the "stars" has moved, that will be Hebe. Happy hunting! □

Rick Shaffer is a technical group leader at the Jet Propulsion Laboratory in Pasadena, California. He leads the data management team on the Ulysses mission, a spacecraft on its way to Jupiter and the Sun.

The Solar System August 1991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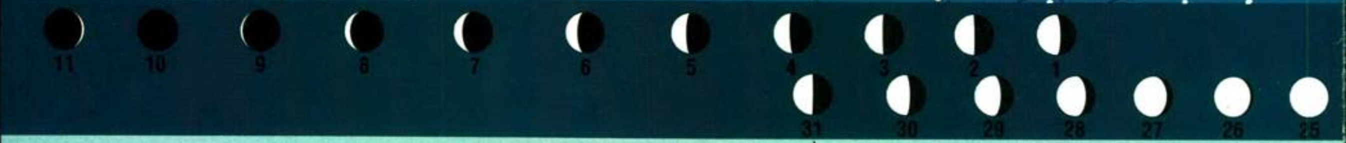
Hebe is at opposition on August 27

Dembowska is at opposition on August 14/15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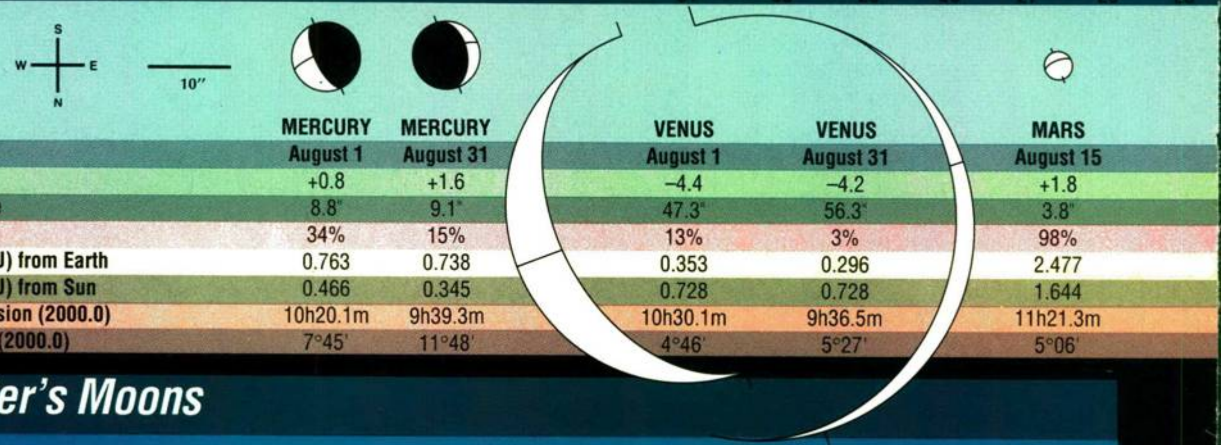
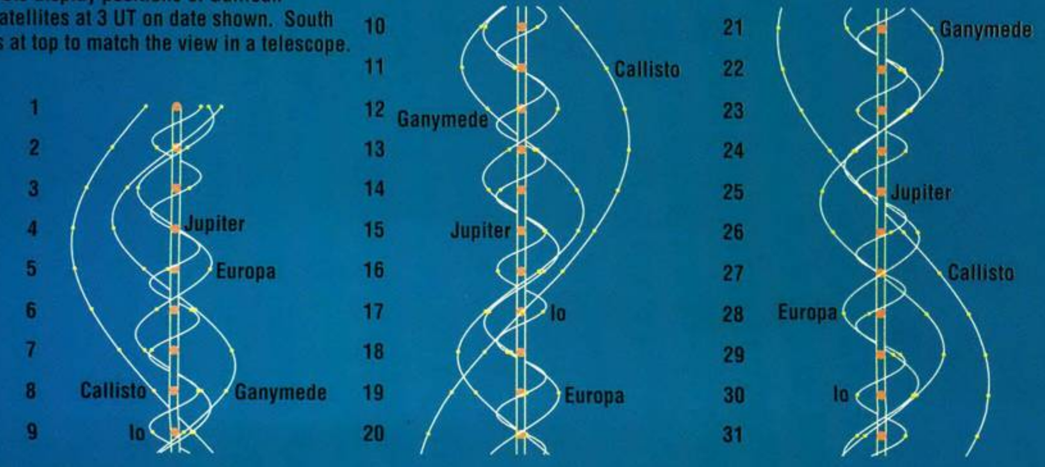
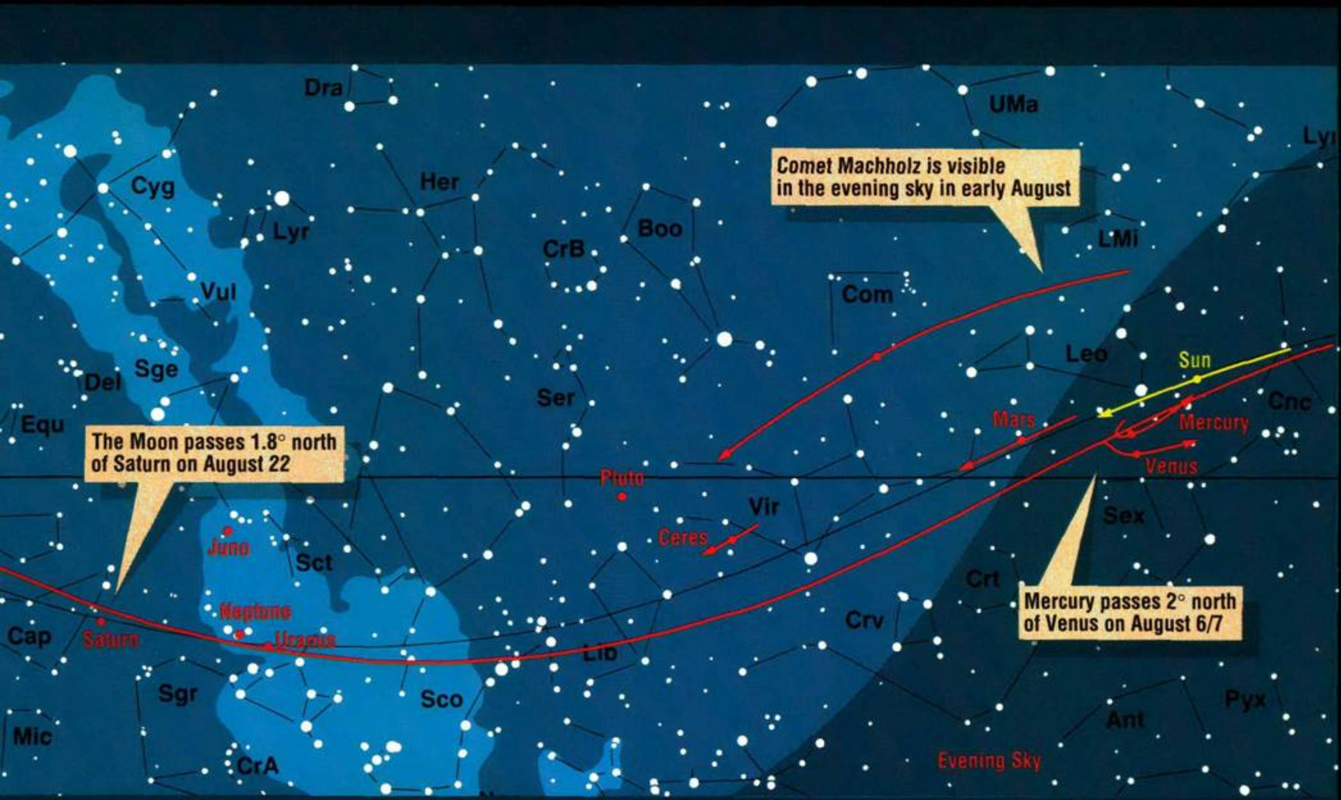


Planet	MERCURY	MERCURY	VENUS	VENUS	MARS
Date	August 1	August 31	August 1	August 31	August 15
Magnitude	+0.8	+1.6	–4.4	–4.2	+1.8
Angular Size	8.8″	9.1″	47.3″	56.3″	3.8″
Illumination	34%	15%	13%	3%	98%
Distance (AU) from Earth	0.763	0.738	0.353	0.296	2.477
Distance (AU) from Sun	0.466	0.345	0.728	0.728	1.644
Right Ascension (2000.0)	10h20.1m	9h39.3m	10h30.1m	9h36.5m	11h21.3m
Declination (2000.0)	7°45′	11°48′	4°46′	5°27′	5°06′

Jupiter's Moons

Dots display positions of Galilean satellites at 3 UT on date shown. South is at top to match the view in a telescope.

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Comet Machholz is visible in the evening sky in early August
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Leo
Sun
Ser
Cnc
Equ
Mars
Mercury
The Moon passes 1.8° north of Saturn on August 22
Pluto
Venus
Vir
Sex
Juno
Ceres
Sct
Crt
Neptune
Mercury passes 2° north of Venus on August 6/7
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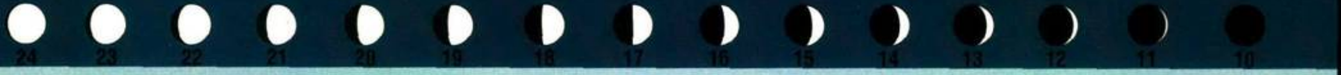
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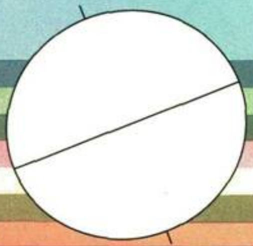
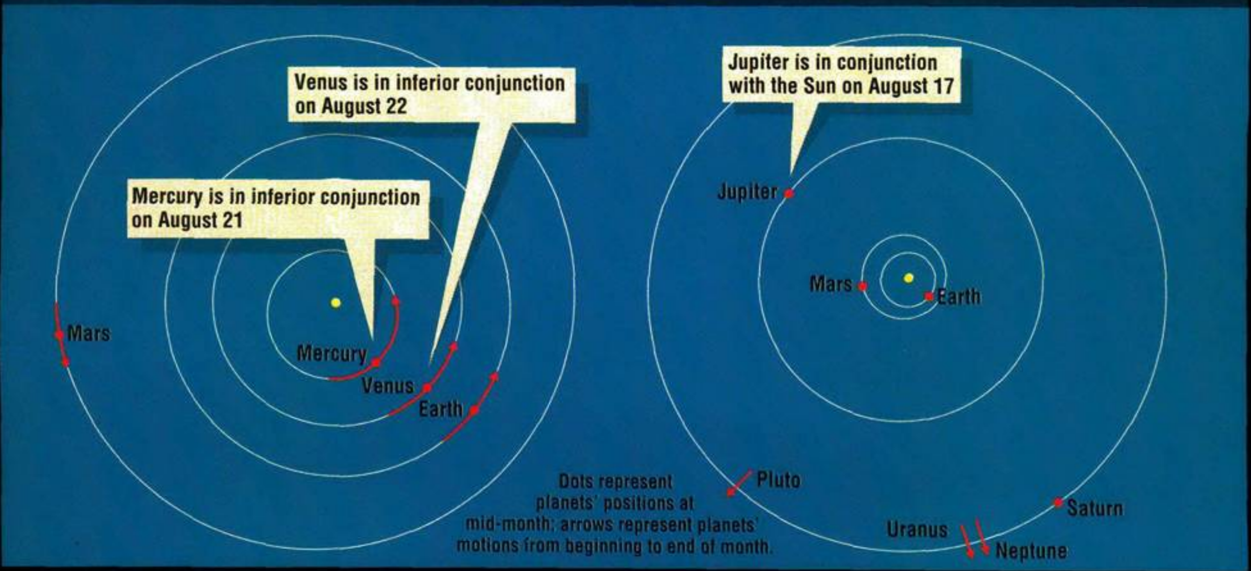


JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
August 1	August 15	August 15	August 15	August 15
−1.7	+0.2	+5.6	+7.9	+13.7
31.1"	18.4"	3.7"	2.3"	0.1"
100%	100%	100%	100%	100%
6.335	8.999	18.713	29.385	29.730
5.349	9.959	19.485	30.198	29.678
9h34.3m	20h18.5m	18h45.6m	19h02.8m	15h17.8m
15°14'	−20°09'	−23°25'	−21°51'	−2°42'

The Planets in Their Orbits


Venus is in inferior conjunction on August 22
Mercury is in inferior conjunction on August 21
Mars
Mercury
Venus
Earth
Jupiter is in conjunction with the Sun on August 17
Jupiter
Mars
Earth
Pluto
Saturn
Uranus
Neptune

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

Snapping the Planets Electronically

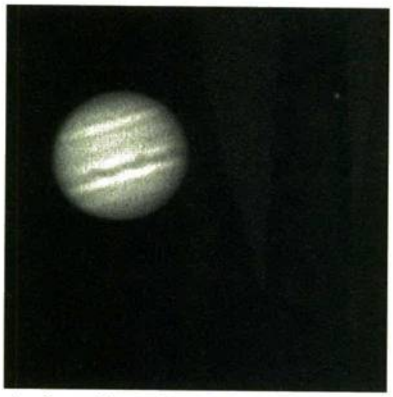
You'll capture exquisite detail when you turn your CCD camera toward the Moon and planets. The secret is choosing the optimum focal length and exposure.

by Richard Berry

Whether you use film, videotape, or a CCD, the secret to taking good planet and Moon pictures is matching the image from the telescope to the type of detector. Planetary photographers discovered long ago that medium-speed films and long focal ratios gave the best match between the image and the detector. Videotaping the Moon and planets likewise requires long focal ratios and the most sensitive video cameras available.

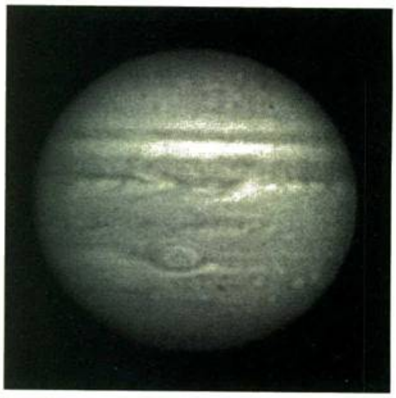
But with CCDs, it's a different ball game. Because CCDs have very small pixels, it is not necessary to greatly enlarge the image of a planet, and because the image is small and bright, the exposure times are short. With a CCD camera, you get the optimum results using short focal ratios and short exposure times.

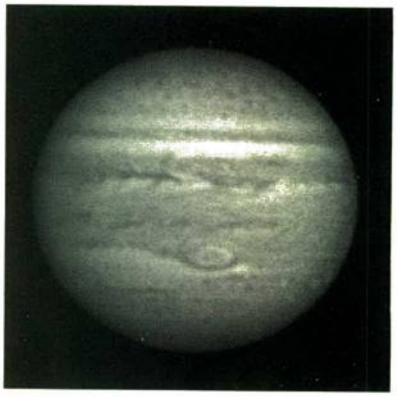
Here's how you can match the telescope to a detector. To capture all the detail in a telescopic image, any detector — film, video, or CCD — must be able reproduce the finest details in an image. A rule of thumb in communications called the Nyquist sampling theorem states that when you make two measurements per resolution element, you record nearly all of the information in an image.


Jupiter with an Ultima 8 at f/22

The Lynxx, Santa Barbara, and Electrim cameras have pixels that are not quite square. Each pixel measures 0.00054 by 0.0006 inch. At f/40, the brightest part of the Airy disk in a perfect telescope is 0.0010 inch in diameter and thus covers two pixels on the CCD.

By fortunate coincidence, an 8-inch telescope at f/40 produces an image of Jupiter that fills about two-thirds of the diameter of the TI-211 CCD chip used in the Lynxx, Santa Barbara, and Electrim cameras. In other words, Jupiter's image size is just about perfect. In lunar imaging, a big crater like Clavius fills the full width of the frame.


Jupiter with a 16-inch at f/25


In 45 minutes Jupiter has rotated.

Relatively short focal ratios confer an additional advantage to the CCD imager: the image is bright. This means that exposure times with CCDs are short compared to those in astrophotography. CCDs benefit from the same brief moments of perfect seeing that allow visual observers to pick out delicate lunar and planetary detail.

You can calculate the exposure time with a modified version of the astrophotographer's equation (see How Long an Exposure?). You simply plug in the focal ratio and the brightness value for the subject and use the answer as your starting exposure.

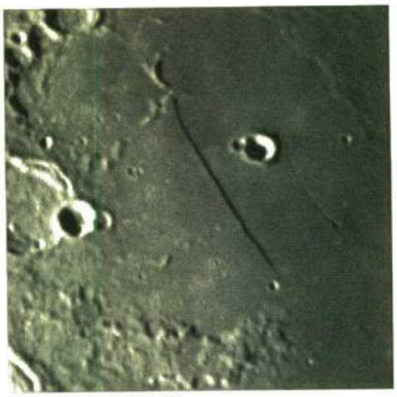
Because CCDs are so new, few amateur astronomers and astrophotographers have had the opportunity to try them. One of the pioneers is Donald Parker, known for his out-

For Best Results: f/20 to f/40

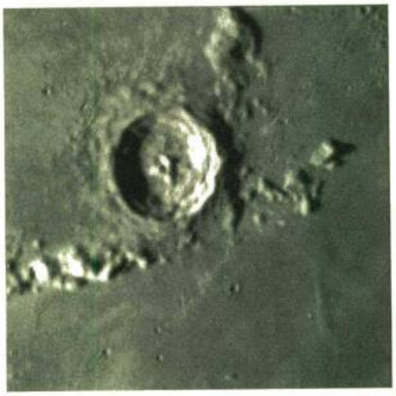
The best theoretical match between the TI-211 CCD chip used in the Lynxx, Santa Barbara, and Electrim cameras and your telescope's optical system occurs at f/40. At this focal ratio, the bright core of the Airy disk spans two pixels and therefore satisfies the Nyquist sampling theorem. If this condition is met, the CCD chip captures almost all of the information present in the telescopic image, and further enlargement of the image will yield little new detail.

Use eyepiece projection.

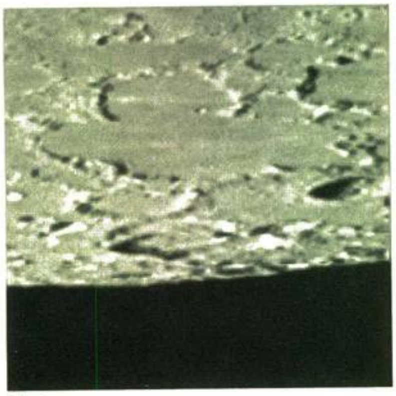
However, the practical astrophotographer may discover that the best pictures on unsteady nights result from somewhat shorter focal ratios, perhaps f/30, f/25, or f/20, depending on the seeing. The shorter focal ratios require shorter exposures and thus help "freeze" seeing.



The Straight Wall



Eratosthenes

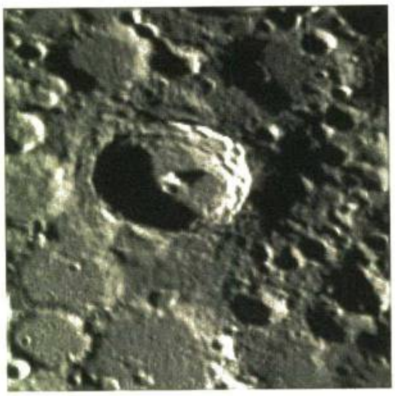


Meton

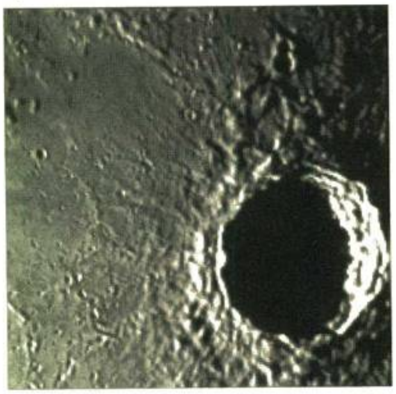
How Long an Exposure?

You can calculate the exposure times for CCD pictures almost exactly as you would for astrophotographs. The astrophotographer's equation gives the exposure time. To evaluate the exposure, E, in seconds, plug in the maximum pixel value in the image, P_{max}, and the pixel value you want for the object, P. For the Lynxx camera, these values should be 4,095 and 3,200 respectively. F is the effective focal ratio, S is the speed of the CCD (use a value of 80 in the case of the Lynxx), and B is the brightness of the object. B equals 30 for Jupiter, 60 for Mars, 10 for Saturn, 20 for the crescent Moon, 40 for the Quarter Moon, 80 for the gibbous Moon, and 200 for the Full Moon. See the January 1985 ASTRONOMY for more information on exposure.

$$E=(P/P_{max})(F^2/SB)$$

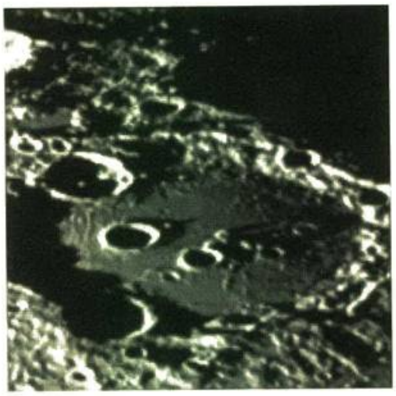


Tycho

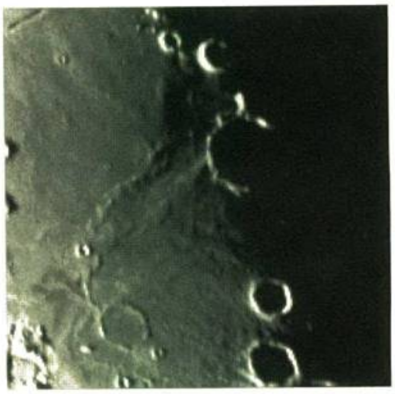


Copernicus

LUNAR FEATURES are rendered in sharp detail when you match your telescope's optical capabilites to the recording capabilities of the CCD chip.



Clavius



Bullialdus

standing planetary photography. Two of Parker's images of Jupiter taken with a SpectraSource Lynxx CCD camera show the remarkable quality CCDs can deliver. (Also see a sequence of six images of Jupiter in the June ASTRONOMY, on pages 90 and 91.) The pictures were taken with Parker's 16-inch f/5 Newtonian reflector, using eyepiece projection for an effective focal ratio of f/26. The exposure was 1/4 second. For comparison, when Parker photographs Jupiter on Ektachrome 200, he uses a 2-second exposure at f/120.

In this story, all of the Moon pictures and the small image of Jupiter were taken with an Ultima 8 telescope using eyepiece projection to f/22. Exposures ranged from 1/20 second on bright highland areas to 1/2 second for dark mare areas and craters near the shadow-line, and Jupiter required an exposure of 0.15 second. The camera used was SpectraSource Lynxx.

Making images with a CCD feels more like visual observing than taking pictures. It's delightful to see each image appear on the monitor moments after it's been taken. If the seeing is poor or if the image is out of focus, you just take another picture. In Miami, where the atmosphere is usually extremely steady, Don Parker saves every third or fourth frame he shoots. In other parts of the country — like Milwaukee — you may need to shoot a dozen or more frames to get one worth saving.

There is a lot of satisfaction in shooting high-resolution images of the Moon and planets, whatever the medium. CCD images complement the abilities of film and video to record the features of the planets. It's just a simple matter of matching a new type of detector to your telescope and you'll be snapping the planets — electronically. ☐

Catch a Cosmic Streaker

If you've never taken a photograph of a meteor, this month's excellent Perseid shower offers an ideal opportunity.

by Robert Burnham

Zzzziiippppp!

You can almost hear them dash through the upper atmosphere. One in ten — or one in a hundred — will blaze with fireball brilliance, casting spooky moving shadows on the ground as it streaks a luminous line across the sky.

A good meteor shower is spectacular, and capturing meteors on film is easy. The only essentials are an adjustable camera, a tripod, and medium-fast film. Even skill isn't that important, because catching a meteor on film involves large amounts of luck. In this total beginners stand equal to experienced backyard astronomers and have chances just as good of taking a photo that anyone would be delighted with.

This month's Perseids (in the wee hours of August 13) is the year's best meteor shower. The Moon will set early, keeping the sky dark, and the shower actually lasts a couple of days. Thus if the night of the 12th to the 13th promises clouds, try a day before or after. (For all the details on this shower and a list of others, see "Night of the Falling Stars" on page 64.)

The Basic Setup

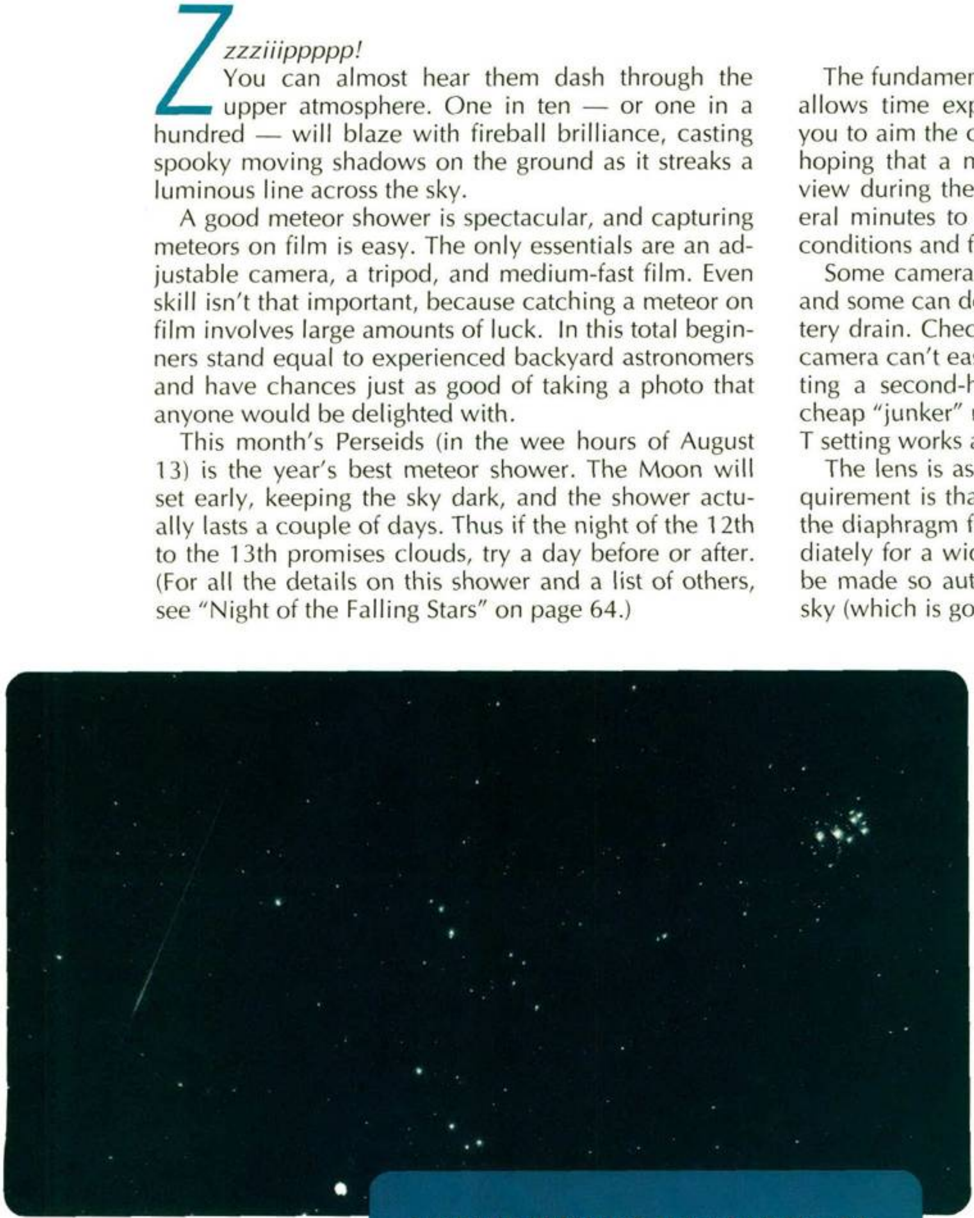
The fundamental item is a camera with a shutter that allows time exposures. Meteor photography requires you to aim the camera at the sky and open the shutter, hoping that a meteor will streak through the field of view during the exposure. Typical exposures run several minutes to half an hour, depending on local sky conditions and film speed.

Some cameras are not designed for time exposures, and some can do it only at the expense of a steady battery drain. Check your camera manual. If your regular camera can't easily make time exposures, consider getting a second-hand one. It needn't be expensive: a cheap "junker" may serve perfectly if the camera's B or T setting works and the film advance operates.

The lens is as important as the shutter. The main requirement is that you can focus it to infinity and open the diaphragm fully. Some photographers reach immediately for a wide-angle lens, but the choice shouldn't be made so automatically. A wide-angle covers more sky (which is good), but typical wide-angle lenses have slower f/ratios than most normal lenses. This can be bad. Because the bright image of a meteor spends only a fraction of a second on any given area of the emulsion, recording many meteors may call more for a high-efficiency lens than a wide-angle one.

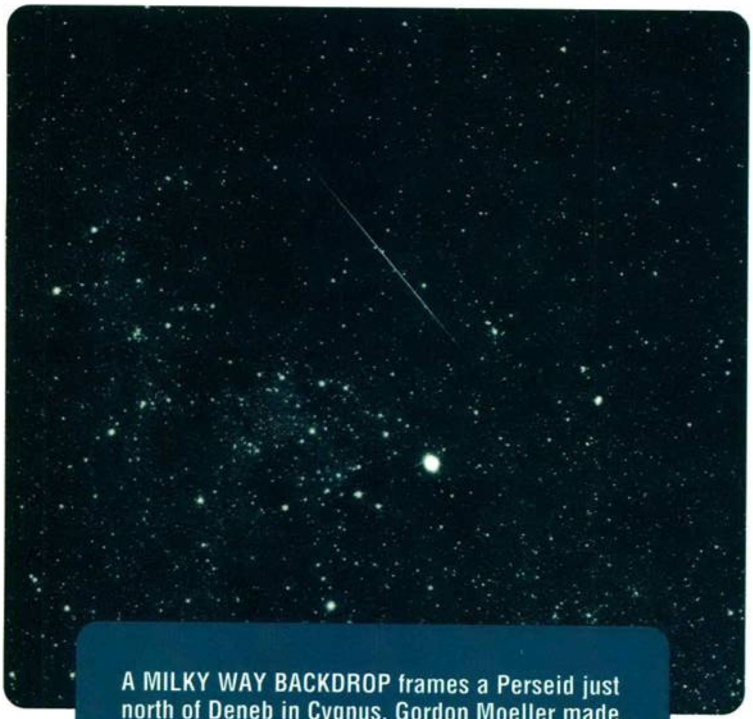
How do you find the balance? Start by comparing the relative efficiency of your lenses. Lens efficiency equals the focal length divided by the square of the f/ratio. For example, a 28mm f/2.8 wide-angle lens has a relative efficiency of 28 ÷ (2.8 x 2.8) = 3.6. By contrast, a 50mm f/1.4 normal lens has an efficiency of 50 ÷ (1.4 x 1.4) = 25.5, a seven-fold gain.

Naturally, there's more to this than simple efficiency. The 28mm lens "sees" almost three times as much sky. But even if you multiply 3.6 by the greater coverage, the wide-angle still comes out far behind the normal



A PERSEID IN TAURUS. Using Tri-X film, Eric Coulter took a guided piggyback shot of Taurus on August 12, 1980, when this Perseid slipped past his 50mm f/1.4 lens.

A PERSEID FROM THE PLEIADES was caught by Martin Germano's 50mm f/1.4 lens on August 12, 1981; he used Tri-X film.



A MILKY WAY BACKDROP frames a Perseid just north of Deneb in Cygnus. Gordon Moeller made the piggyback photo August 11, 1975, with a 35mm f/2 lens and Tri-X film.

lens, and this holds true until the f/ratio of the normal lens reaches f/2.2.

What's the bottom line? While a fast 50mm lens covers less sky, it can still catch more meteors by nabbing the faint ones that pass through its field of view.

Choosing a Film

The best films for meteor photography have an ISO (ASA) of 200 to 400, and choosing between slides or prints depends mainly on how you want to view them. There is no single right film for all cameras, meteor showers, or localities.

The big enemy is sky fog. As minutes pass with the shutter open while you wait for a meteor to scoot by, light from the sky is brightening the frame. Eventually it washes out most star trails and, of course, any meteors. Experienced sky photographers know that before you set out to pluck a Perseid you need to determine the limiting exposure time for a given lens and film on a dark, moonless night at your intended site, be it backyard or back-country.

Take a series of star trail photos using the same camera, lens, and film as for the Perseids, logging the times in a notebook. Start at 1 minute and go up to at least an hour, doubling the exposure time each frame. Have the film processed and examine the results under good light. Look for the frames that show the faintest star trails. (By the way, it's not unusual to catch a sporadic meteor during the tests.) Now check your notebook to discover how long those exposures ran. Whether it's 5 minutes or 55 minutes, this represents the maximum

CUTTING ACROSS STAR TRAILS, this Perseid flared bright but died abruptly. Scott Patterson caught it on August 11, 1974, with a 55mm lens at f/1.8 on Tri-X pushed one stop to ISO 800.

PINK PERSEID MEETS BLUE STAR: Tim Pickering took this photo with a 50mm f/1.4 lens on Ektachrome 400 on August 11, 1983.

time you can leave the shutter open before sky fog starts to decrease the number of meteors you catch. However, if your sky is very bright, the exposure may run too short to have much chance of getting a meteor. In this case try closing down the lens one or two stops until the exposure lasts at least 10 minutes, or use a lens with a slower f/ratio.

Aiming a camera skyward is simple — most meteor photographers use a tripod, the sturdier the better. But if all you have is a picnic table or stone wall, that's fine too — just prop the camera securely with a book, a rock, or a jacket.

Where should you aim the lens? It's best not to point directly toward the radiant. Meteors caught close to the radiant have short trails that many photographers dislike. If you aim away from the radiant the streaks run longer but this introduces an element of chance. Aim too close and you get short streaks; aim too far and the diverging meteor trails will spread so thin it's unlikely the shot will catch any. Many photographers, resorting to a kind of voodoo, feel that the best place to aim is 45° to 60° away from the radiant. This gives a longish streak and keeps the chances fairly high that a shower meteor will pass through the frame.

Handy Extras

A couple of extras can make for better — or at least easier — evenings of picture taking:

Cable release. This useful accessory lets you squeeze off exposures in the dark with less jiggling of the machinery. Also, if your camera has only a B shutter setting, you'll need a cable release that locks.

Lens hood. This keeps stray light from accidentally getting into the frame. It also slows the formation of dew on the front element of the lens.

Hair dryer. There's nothing better to remove dew or frost from the lens (or the photographer). If your site has no electric power available, 12-volt blowers are available to plug into a car's cigarette lighter.

Equatorial mounting. Some photographers like stars to look like stars, so they piggyback their camera on a telescope. This way they get at least a nice star field photo. Just be sure the front end of the tube or finderscope isn't visible in the frame.

Meteor photography is a great activity, whether pursued in solitary fashion or among a group. (Groups, with several cameras available, can stake out whole regions of sky and the chances of somebody's getting something come close to certainty.) Meteor photography is also the easiest celestial photography of all and its results can rank among the most stunning.

So this month when the Perseids begin to pop — why not give it try? □

The Distant Suns

Journey to the outer limits of the Galaxy to observe gigantic spheres of ancient stars.

by David Higgins

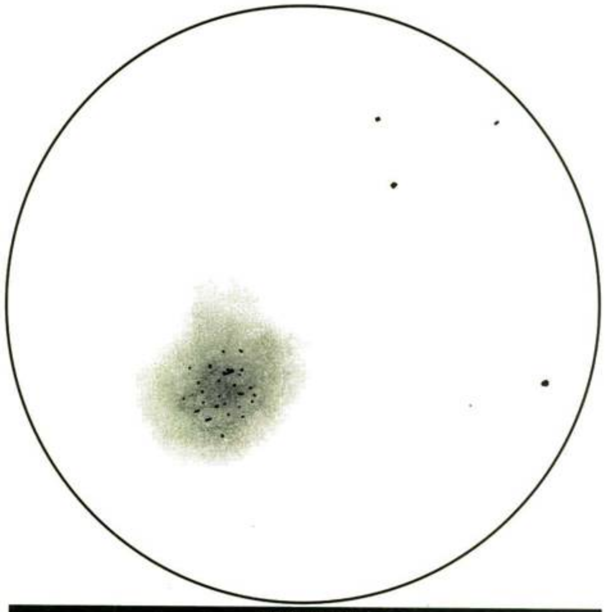
Globular star clusters are some of the most beautiful and challenging deep-sky objects visible in amateur telescopes. Enormous spheres of ancient stars, they are extraordinarily large and bright when compared with, say, our solar system. Most globulars measure hundreds of light-years across and glow with the light of tens of thousands of Suns. Globular clusters are found in an enormous spherical halo surrounding the central bulge of the Galaxy. Over extremely long periods — tens of millions of years — the clusters orbit the center of the Galaxy in paths highly inclined to the galactic plane.

The unusual nature of these objects as semi-independent communities of stars outside the Galaxy's disk remained unknown until less than a century ago. Rather than condensing into the Galaxy's disk — the fate of most of the gas and dust that went into the Milky Way — globulars formed from blobs of material that escaped being pulled into the disk.

Today, twelve billion years later, they appear in the eyepiece as fuzzy disks of gray-green light surrounded by a peppering of faint, resolved stars. A given cluster's brightness, size, and the amount of detail you'll be able to resolve all depend on your telescope and the individual cluster you're observing. Globular clusters vary considerably in size and brightness. Additionally, these intrinsic differences appear exaggerated because the clusters lie at a wide range of distances. The clusters we'll explore lie at distances of 7,500 light-years to more than 110,000 light-years. Yet the views of globulars depend on more than just their distances: some are heavily obscured by intervening dust and gas.

But one thing is constant with all globulars: they let you reach back into the early days of the Galaxy and see some of the oldest objects known.

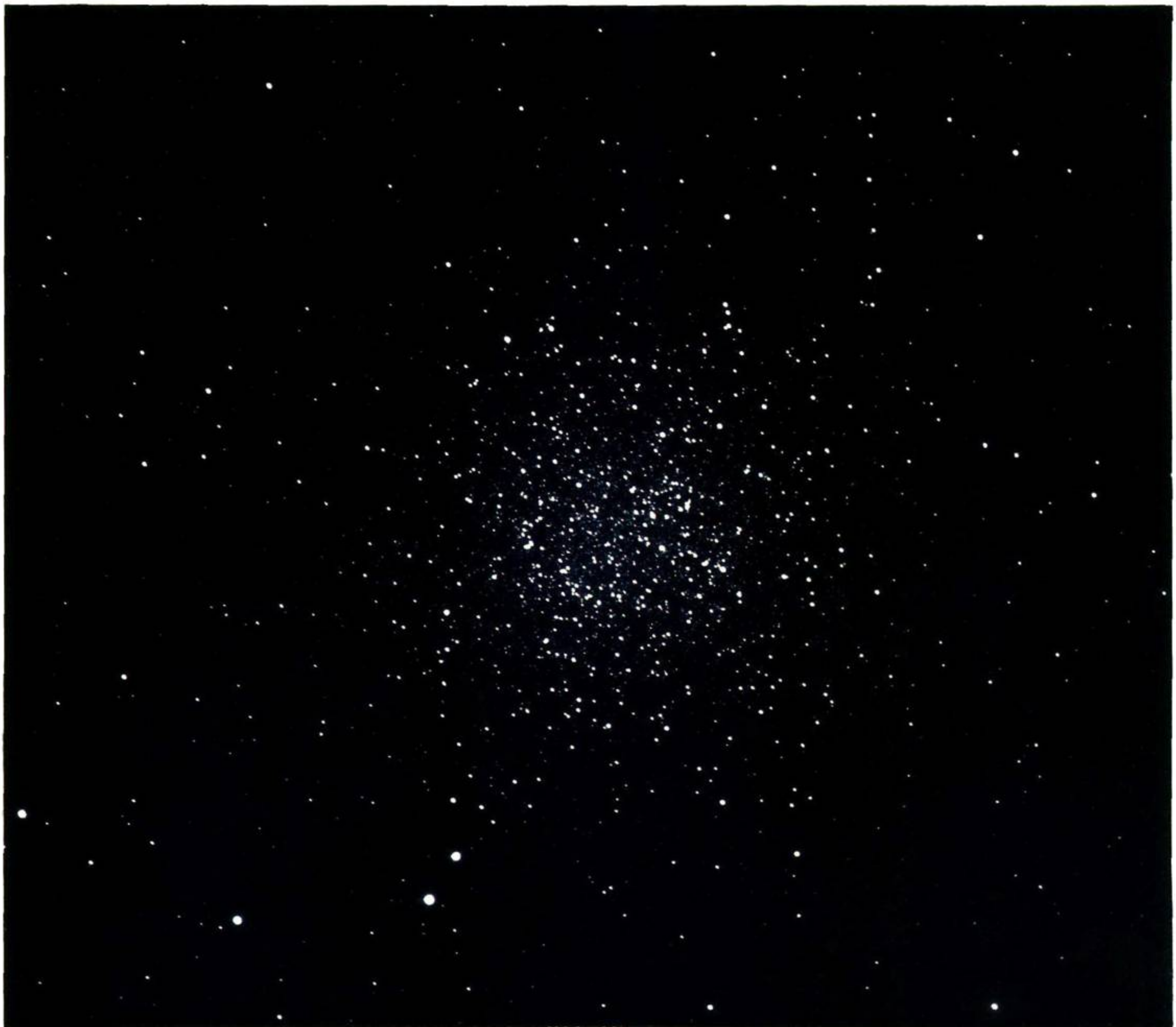
The first time you observe challenging globular clusters you might be struck by an apparent contradiction. If they're large, bright objects, why do they appear rather faint and challenging in the eyepiece? **NGC 5897** is a superb example of a challenging globular. Located in the dim constellation Libra the Scales, this 8.6-magnitude globular is large but has a low surface brightness. Measuring 12.6' across and lying at a distance of nearly 40,000 light-years, NGC 5897 is simple to find but not so simple to resolve into stars. To locate NGC 5897, start by aiming your telescope toward the 2nd-magnitude star 20 Librae. Next, draw an imaginary line northeast to 35 Librae. NGC 5897 lies about halfway between these two stars.



NGC 5897
12.5-inch f/4 reflector at 150x by Jeffrey L. Corder

In an 8-inch scope fitted with a wide-field eyepiece, NGC 5897 appears as a soft glow elongated east-west. You can resolve the edges of this cluster with moderate magnifications, but because NGC 5897 has a low surface brightness the entire cluster appears to vanish into the sky background if you use too much power. Larger scopes show NGC 5897 as a faint glow with some central brightening. The cluster's core is partially resolved at medium magnifications. Through a 17.5-inch or larger instrument NGC 5897 appears like a faint spiral galaxy. As you increase the magnification in a large scope, NGC 5897 appears fainter, but a handful of stars scattered across the core comes into view. Several strings of stars that heighten the spiral effect are visible extending east-west across the cluster.

Much closer to home than NGC 5897 lies **NGC 6539**, a cluster lying on the border between Serpens

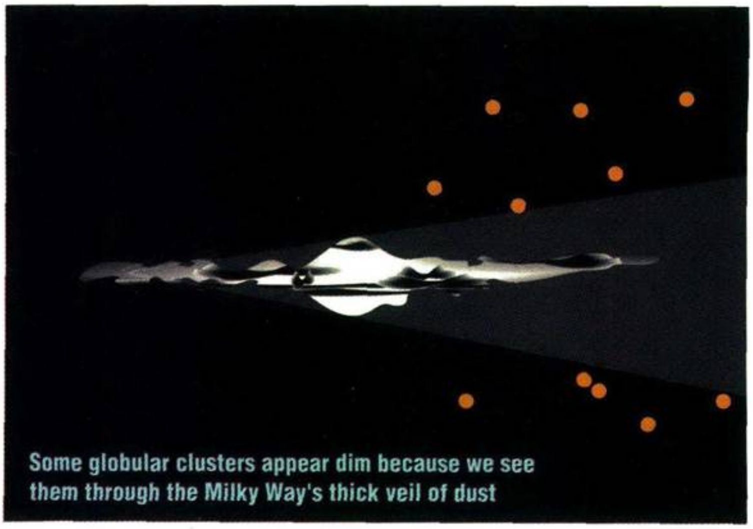


NGC 5897
Mag. 8.6 Size 12.6' Palomar Mountain Observatory photo

Challenging Globular Clusters

Object	R.A.(2000.0)	Dec.	Mag.	Size
NGC 5694	14h39.6m	-26°32'	10.2	3.6'
NGC 5897	15h17.4m	-21°01'	8.6	12.6'
NGC 6229	16h47.0m	+47°32'	9.4	4.5'
NGC 6517	18h01.8m	-8°58'	10.3:	4.3'
NGC 6539	18h04.8m	-7°35'	9.6:	6.9'
IC 1276	18h10.7m	-7°12'	?	7.1'
NGC 7006	21h01.5m	+16°11'	10.6	2.8'

Object: *Designation in NGC or IC catalog.* **R.A. and Dec.:** Coordinates in equinox 2000.0. **Mag.:** V magnitude of cluster. **Size:** Diameter in arcminutes.



Some globular clusters appear dim because we see them through the Milky Way's thick veil of dust

NGC 7006
Mag. 10.6 Size 2.8' by Preston Scott Justis

Cauda and Ophiuchus. Although it's close — only 7,500 light-years away — this cluster is obscured by dust and appears fainter than NGC 5897. NGC 6539 suffers from low surface brightness. In small scopes it appears as a faint haze with no central brightening. In larger scopes, the unresolved haze appears irregular in shape. In a 17.5-incher the haze appears larger but is not resolved into stars. With averted vision the cluster takes on a grainy appearance — it's on the verge of resolution — across the core. A string of faint field stars is visible on the western edge. Low magnifications seem to give the best views of NGC 6539. High magnifications make the object appear too faint.

More than three times as distant as NGC 6539 is the faint and challenging globular cluster **NGC 6517**. Intrinsically brighter than either NGC 6539 or NGC 5897, NGC 6517 is relatively easy to find, despite its distance of 25,000 light-years. To locate NGC 6517, start at the 2nd-magnitude star 64 Ophiuchi. Extend an imaginary line to the northeast about 2° and you'll come to 69 Ophiuchi. NGC 6517 lies at the midpoint of this line. NGC 6517 measures 4.3' in diameter and glows at magnitude 10.3. In small scopes it gives the appearance of a small glowing ball with little central brightening.

Larger scopes do not improve the view much. The core appears brighter and a haze becomes visible surrounding the nucleus. In 17.5-inch or larger scopes, the haze surrounding the core becomes granular in appearance. Try high magnifications with this cluster.

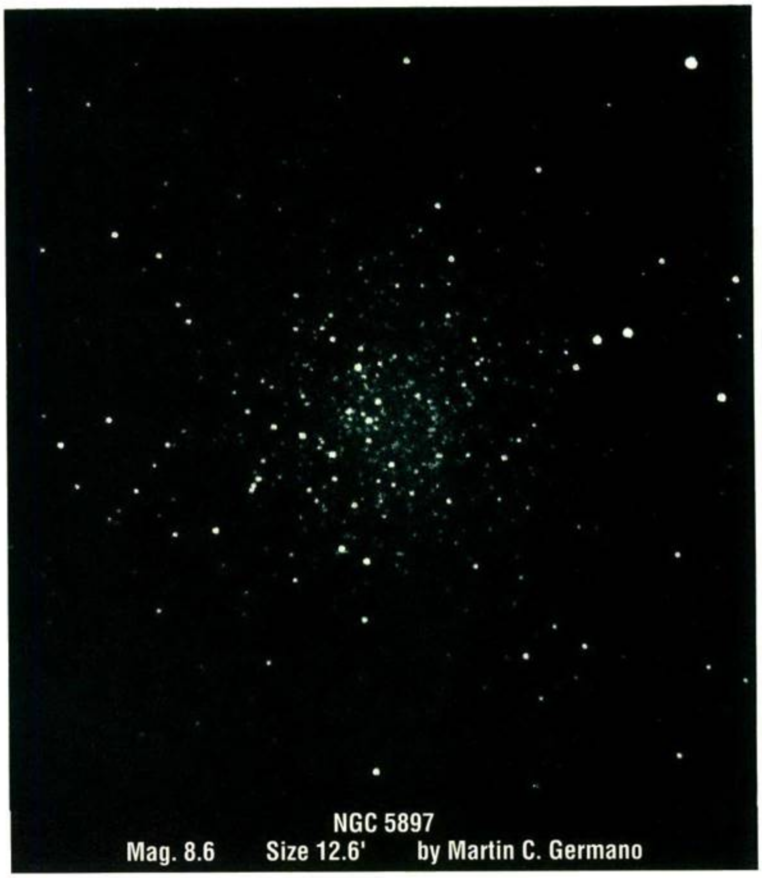
Farther out lies the challenging cluster **IC 1276**, a very difficult object for small telescopes. Heavily obscured and faint, this cluster is far more challenging than NGC 6539 — which lies only 1.5° to the west. Glowing at magnitude 10.3 and measuring 7.1' in diameter, you would think that IC 1276 would not be that difficult of an object to find. Nothing could be farther from the truth. IC 1276 not only lies at a great distance from the Sun, 42,000 light-years, but it is also heavily obscured from all of the gas and dust clouds that lie between us and the cluster. In large telescopes, IC 1276 appears as a faint haze with no central brightening. Averted vision is required for a decent view on nights of other than good seeing. Use low magnifications and wide-field eyepieces to catch a glimpse of IC 1276. Small scope owners will achieve success by simply finding this elusive cluster.

The final three clusters are all very distant objects, all lying far out in the Galaxy's halo more than 100,000 light-years away. They are also approximately the same intrinsic brightness. However, they offer different degrees of difficulty because of varying amounts of interstellar gas and dust that block their light.

NGC 6229 is a small globular cluster in Hercules with a high surface brightness — despite its great distance of 102,000 light-years. Glowing at magnitude 9.4 and measuring 4.5' across, NGC 6229 is not difficult to locate. Start by finding 42 Herculis. Extend an imaginary line about 4.5° to the southeast and you'll come to the bright star 52 Herculis. The cluster lies about halfway along this line and a few arcminutes northeast.

In 6-inch or smaller scopes, NGC 6229 appears as a small, faint, fuzzy ball. Don't hesitate to use high magnification on this cluster, but don't expect to resolve it easily. Twelve-inch and larger scopes begin to resolve the brightest stars in this group. In 17.5-inch

NGC 6229
Mag. 9.4 Size 4.5' by Jack Metcalfe



NGC 5897
Mag. 8.6 Size 12.6' by Martin C. Germano

and larger scopes, NGC 6229 appears much brighter and the core seems like a gritty ball of sand surrounded by a faint haze. With averted vision you'll see some individual stars within this haze.

By using 20 Librae as a starting point we can track down Hydra's most challenging globular cluster, **NGC 5694**. This object lies 105,000 light-years away but is easier to see than NGC 6229 because of less interstellar absorption. From 20 Librae, move about 5° west and you'll find a string of 4th- and 5th-magnitude stars that extends roughly northwest-southeast and ends at the 3rd-magnitude star 58 Hydrae. Two degrees west of this string of stars lies NGC 5694. This small globular glows at magnitude 10.2 and is very concentrated so its surface brightness is fairly bright. NGC 5694 is bright enough that if you don't find it right away you can do some careful sweeping to spot it.

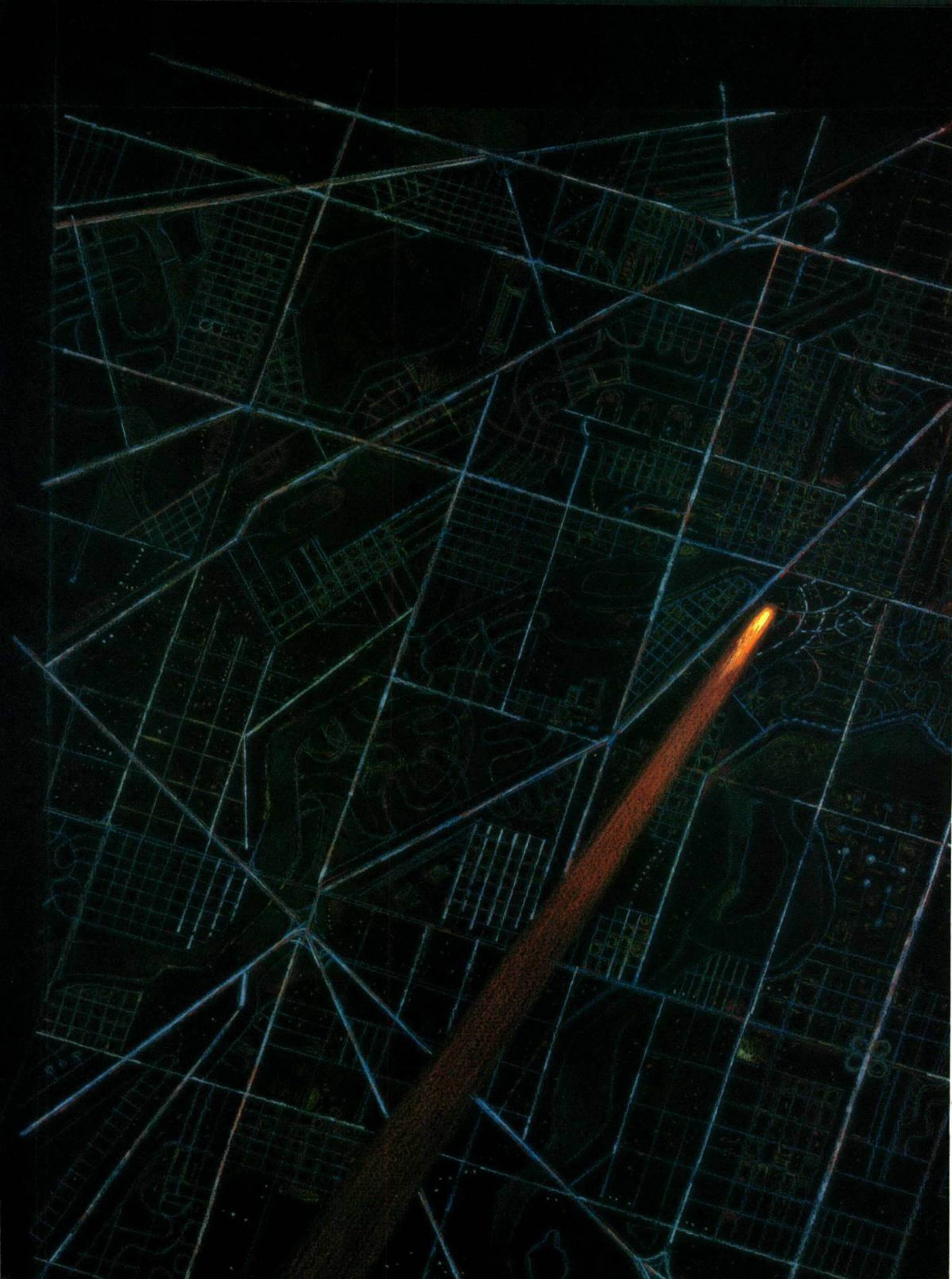
In telescopes 8-inches or smaller NGC 5694 appears as a small bright fuzzy ball. You can use high magnifications on this small cluster but don't expect to resolve it. In larger scopes the core is surrounded by a faint haze that appears somewhat granular in appearance. In the really large backyard scopes the core becomes relatively bright and the surrounding haze is much more granular . Averted vision will show several stars across the face of the cluster.

Delphinus the Dolphin contains **NGC 7006**, our final and most remote globular cluster. Glowing at magnitude 10.6 and measuring only 2.8' in diameter, NGC 7006 is a difficult object for small telescope users. Its apparent faintness is due to both a relatively large distance of 113,000 light-years and some obscuration by dust. Unfortunately no bright stars lie nearby to act as convenient signposts, so star hopping to NGC 7006 takes patience and determination.

The simplest way to find NGC 7006 is to center the 3rd-magnitude star 12 Delphini in a wide-field eyepiece. Move 3.5° east and you'll see NGC 7006 move into the eyepiece field. In 6-inch or smaller scopes NGC 7006 is a faint glow surrounding a somewhat brighter core. For some observers averted vision may be required to see this faint cluster. Scopes in the 12-inch range don't improve the view much although the core becomes a bit brighter and much more concentrated, and the haze that surrounds the core becomes easier to see. Backyard scopes 17.5 inches and larger show a much brighter haze surrounding a concentrated core. Averted vision makes the haze granular and at high powers you will see stars around the edge of the cluster but not across its face.

Each of these globular clusters presents a real challenge for small telescope observers. If you don't see them immediately, don't give up — simply try again on a darker night. As you successfully hunt down these globulars you'll gain experience with seeing faint objects and sharpen your observing skills. You'll also gain an overview of the structure of the Galaxy, a sort of mental, three-dimensional picture of how this vast halo of globulars surrounds the galactic disk. What better way to spend a warm summer evening than basking in the glow of our home Galaxy? ☐

David Higgins is central coordinator of the National Deep Sky Observers Society and a contributing editor of Deep Sky. *He lives in Krebs, Oklahoma.*



Night of the Falling Stars

After midnight on Monday, August 12, turn off the late show and turn on the sky. Plan to watch a different kind of late-night entertainment — the Perseid meteor shower.

by Christopher E. Spratt

Spend any time watching the night sky and you'll see streaks of light occasionally dart across the heavens. If you are with someone unfamiliar with the nighttime panorama, they're sure to exclaim, "Look, a shooting star!"

Of course, stars don't shoot. Nor do they fall. Those brief flashes punctuating the night are properly called meteors. They can be one of the most entertaining and enjoyable attractions of the night sky.

Although meteors can be seen on any clear night, this August promises to bring an evening to remember for meteor watchers. On the night of either August 11/12 or 12/13, set some time aside to spend at least an hour outside. You can watch from your backyard if you wish, but for the best view drive out of the city to a choice spot away from streetlights. Then sit back and watch a celestial late show called the Perseid meteor shower.

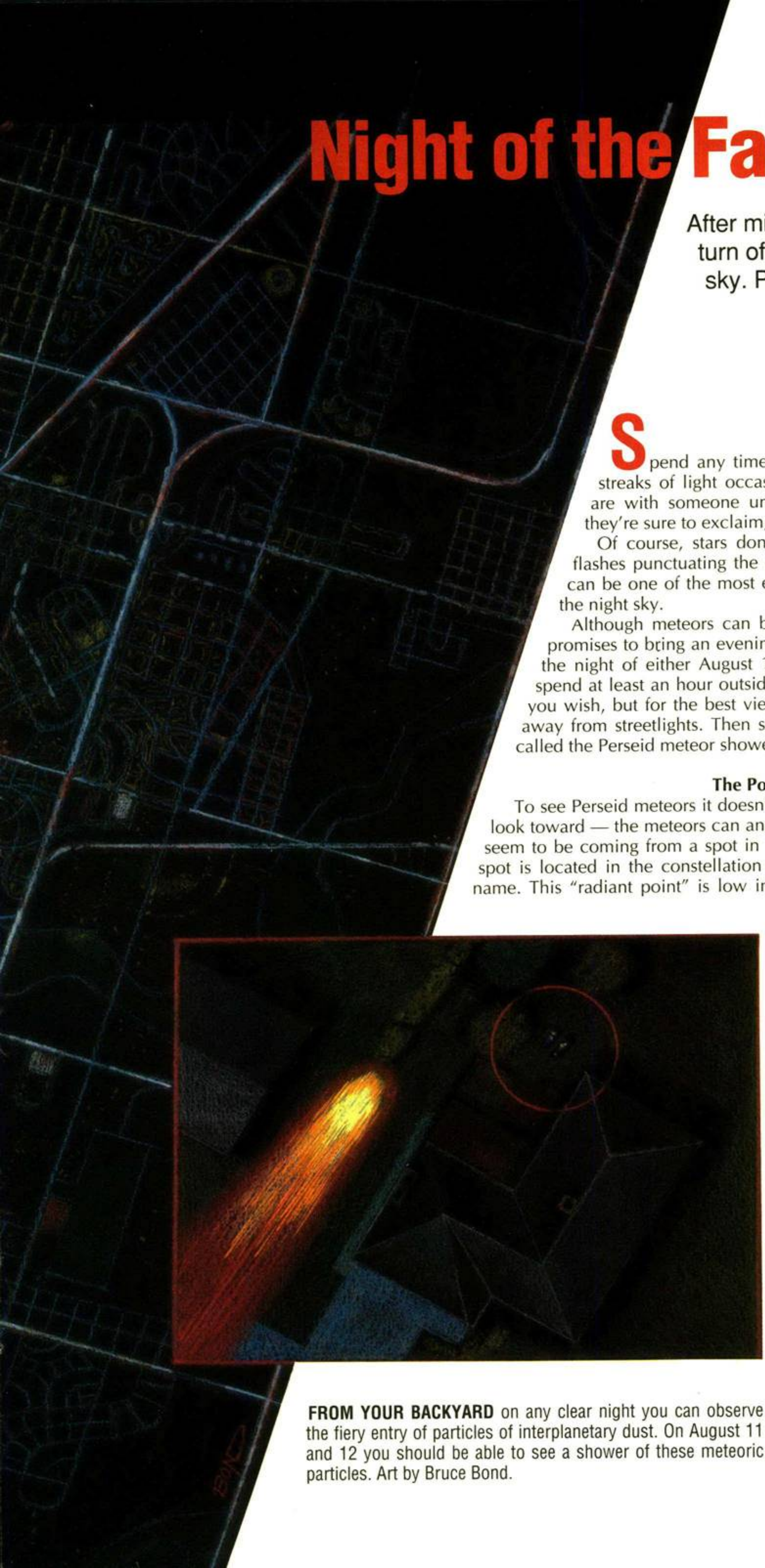
The Popular Perseids

To see Perseid meteors it doesn't really matter which part of the sky you look toward — the meteors can and will appear anywhere. But they will all seem to be coming from a spot in the northeastern sky. To be precise, this spot is located in the constellation of Perseus, which gives this shower its name. This "radiant point" is low in the northeast early in the evening but climbs higher through the night. By 5 a.m. it is almost overhead.

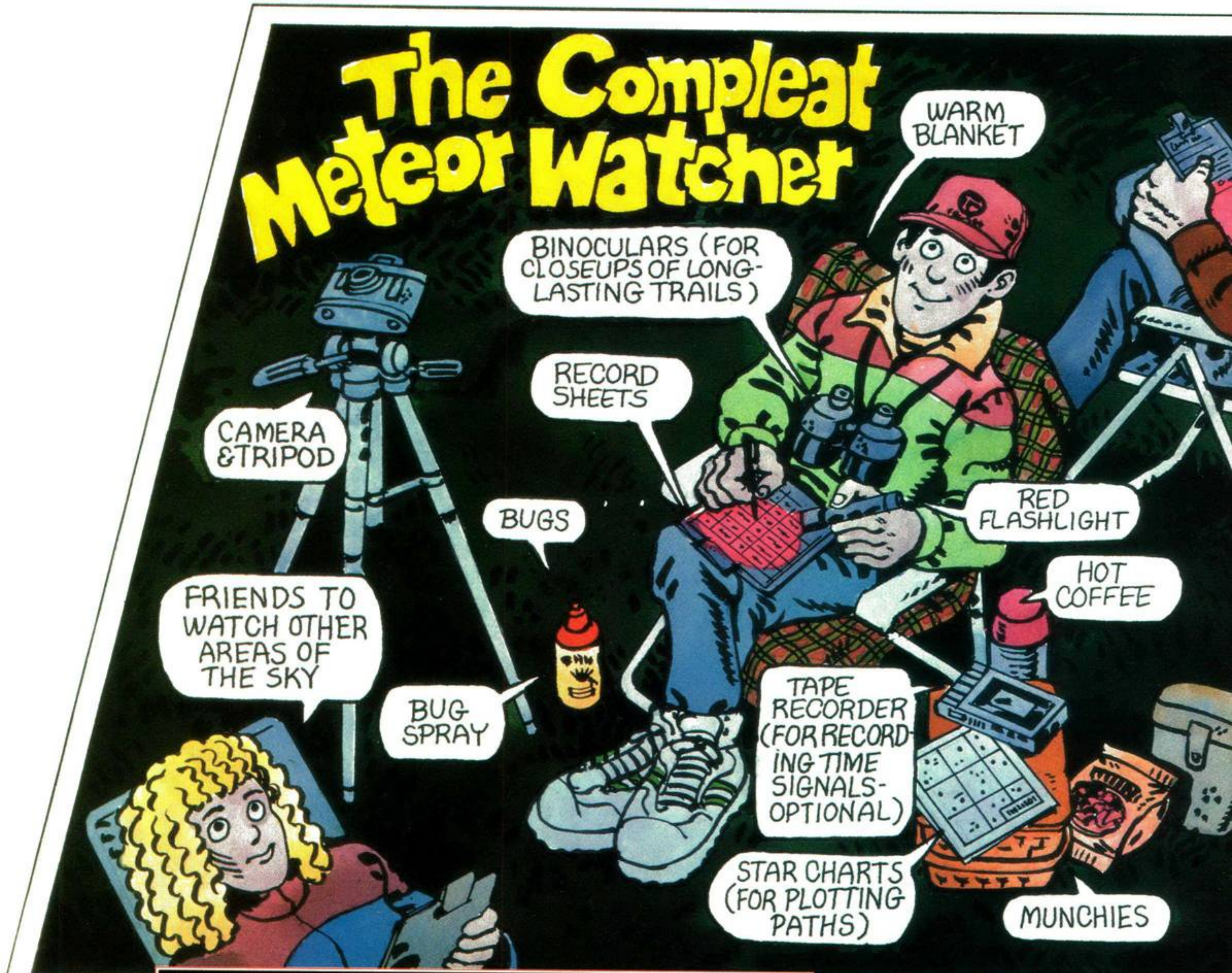
It's difficult to say when the best time to look will be. One authoritative source, the annual *Handbook of the British Astronomical Association,* says the peak of the shower occurs about midnight Eastern Daylight Time (9 p.m. PDT) on the night of August 12/13, a prediction that matches ASTRONOMY's own calculations.

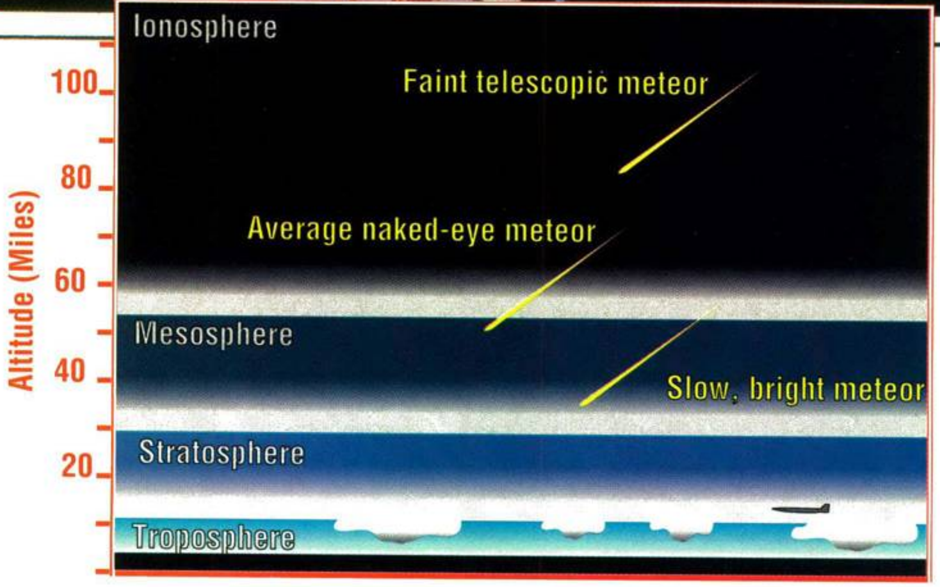
In North America, if you watch between 10 p.m. and 2 a.m. local time on the night of August 12/13 you should see meteors coming thick and fast. The crescent Moon sets between 9 and 10 p.m. local time on August 12 so its light won't interfere with meteor observing for the rest of the night. A general rule of thumb is that you see more meteors after midnight because you are then on the side of Earth facing into the oncoming meteors. We collide with them head on, causing them to strike the atmosphere with greater velocity, making the meteors appear brighter and more numerous.

However, be sure to watch for



FROM YOUR BACKYARD on any clear night you can observe the fiery entry of particles of interplanetary dust. On August 11 and 12 you should be able to see a shower of these meteoric particles. Art by Bruce Bond.

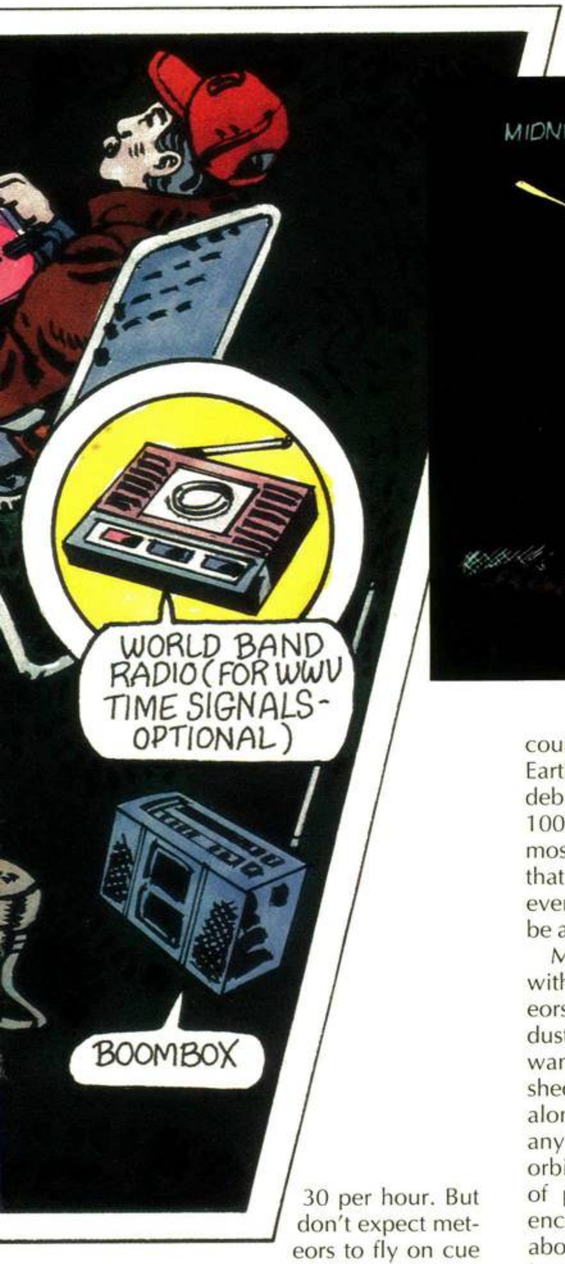

The Compleat Meteor Watcher
WARM BLANKET
BINOCULARS (FOR CLOSEUPS OF LONG-LASTING TRAILS)
RECORD SHEETS
CAMERA &TRIPOD
BUGS
RED FLASHLIGHT
HOT COFFEE
FRIENDS TO WATCH OTHER AREAS OF THE SKY
BUG SPRAY
TAPE RECORDER (FOR RECORDING TIME SIGNALS-OPTIONAL)
STAR CHARTS (FOR PLOTTING PATHS)
MUNCHIES

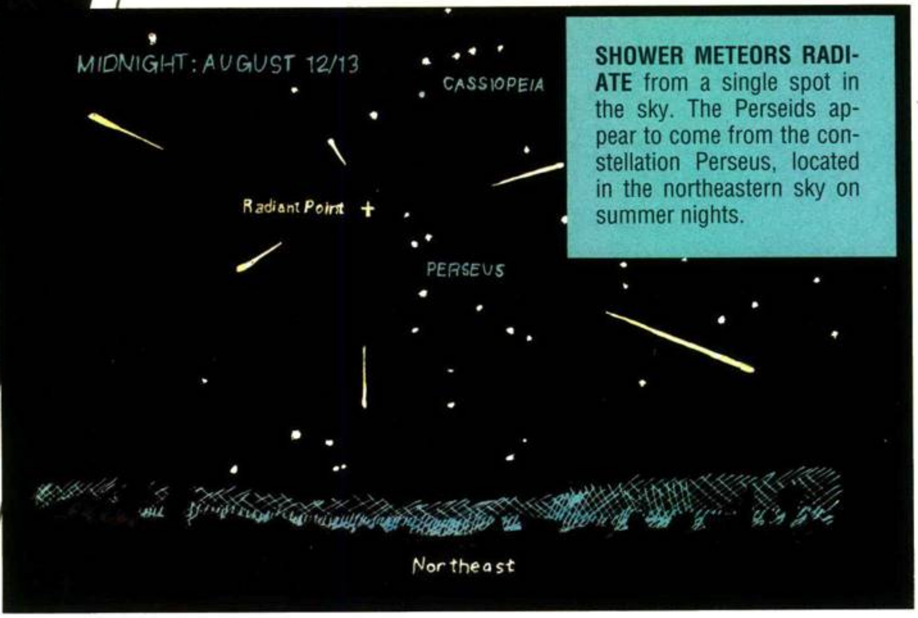

Ionosphere
Faint telescopic meteor
Average naked-eye meteor
Mesosphere
Slow, bright meteor
Stratosphere
Troposphere
Altitude (Miles)
100
80
60
40
20

METEORS COLLIDE WITH THE ATMOSPHERE at great altitudes and great speeds. Small, faint meteors burn up higher than large, bright meteors. All travel at 75,000 to 150,000 miles per hour.

Perseids the night before. Meteors should abound on the night of August 11/12 as well. In fact, the annual *Observer's Handbook* of the Royal Astronomical Society of Canada gives a different time for the peak of the shower — 1 p.m. Eastern Daylight Time on the afternoon of August 12. If this is the case, the nights of August 11/12 and 12/13 should be equally suitable for meteor watching. However, the number of meteors you see will depend more on the clarity and darkness of your sky than on whether you observe right at peak hour.

How many meteors will you see? If you are at a dark rural site, count on about 40 to 80 per hour during the wee morning hours of the 12th and through most of the night of August 12/13, making for an average of about one per minute. If you are amid city lights, expect to see 10 to


WORLD BAND RADIO (FOR WWV TIME SIGNALS - OPTIONAL)
BOOMBOX



SHOWER METEORS RADIATE from a single spot in the sky. The Perseids appear to come from the constellation Perseus, located in the northeastern sky on summer nights.

30 per hour. But don't expect meteors to fly on cue every minute or so. Meteors like to come in apparent bursts — sometimes a half dozen will appear over a couple of minutes followed by several minutes with no activity. Meteor watching requires patience.

Not all meteors will be bright; most will be just visible to the observant naked eye. Some will appear just out of the corner of your eye, making you wonder if you really saw something. But every few minutes you should see a meteor as obvious as the brightest stars, certainly bright enough to make even your non-astronomer friends exclaim in surprise.

Star Dust

The sight of a meteor zipping across the sky evokes a curiosity about what it was and where it came from. Each momentary flash of light is a speck of interplanetary dust burning up high in our atmosphere. In the course of its orbit around the Sun, Earth intersects streams of this dusty debris. In fact, each day about 100 to 1000 tons of it collides with our atmosphere. The number of meteors that can be seen around the world, even when a shower is not on, may be as high as 100 million a day!

Most of this debris is associated with known comets — shower meteors are material ejected from the dusty nuclei of these interplanetary wanderers. Over time the particles shed by comets become spread out along the comet's orbital path. If any part of this path crosses Earth's orbit, we'll pass through the stream of particles each year and experience a meteor shower. There are about a dozen major stream crossings a year, yielding a dozen annual meteor showers that give reliable displays.

The Perseids, which peak around August 12 each year, are probably the best known. The Geminids (December 14) are a close second to the Perseids, with hourly counts of 50 to 75 meteors.

On the night of a meteor shower, if you trace each meteor path on a star chart you'll notice that most paths will point back to a single spot in the sky, the radiant point. In fact, it is the meteor's direction of flight and not its location in the sky that indicates which particular shower, if any, a meteor belongs to.

The reason meteors appear to radiate from a point is due to perspective. All member meteors of a shower share a common orbit and approach Earth on parallel paths. But from our vantage point on the surface of Earth, the parallel tracks coming at us appear to converge in the distance, just like railroad tracks do on the ground. Meteors that appear near the radiant point usually have short trails — we see them coming toward us. Meteors that appear far from the radiant have longer trails — we see them side-on passing by us.

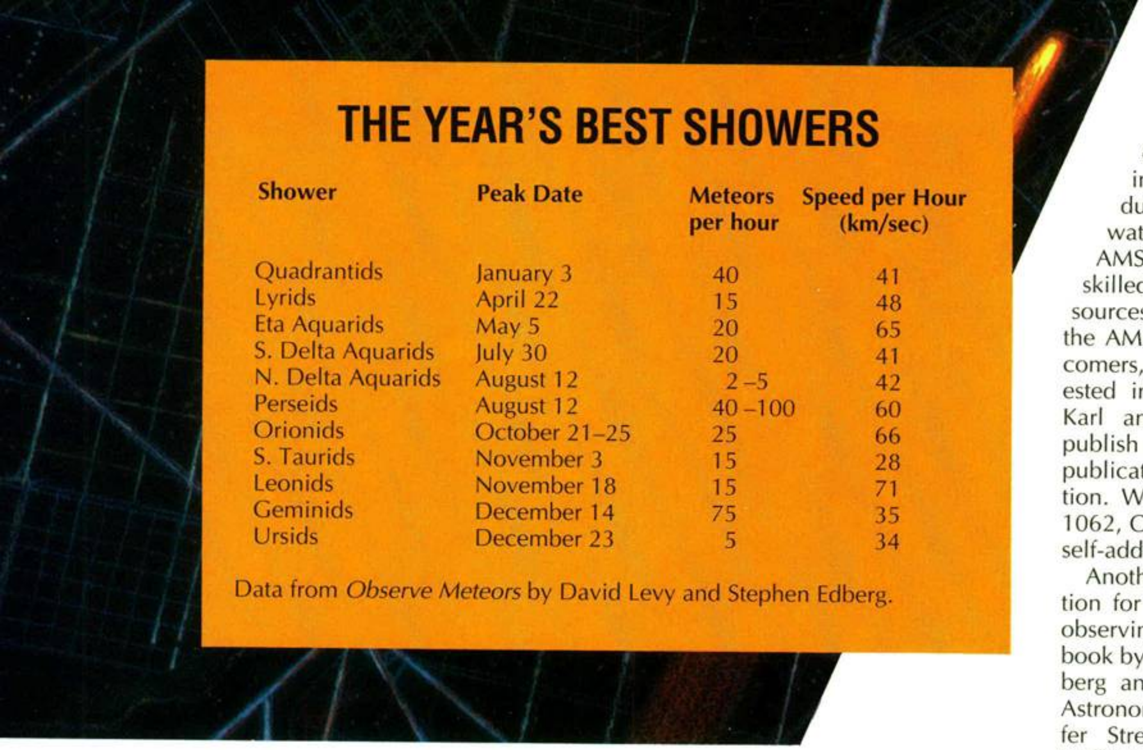
The source streams of meteor showers are transient affairs. Over thousands of years, a meteor stream gradually disperses because of the gravitational tugs from the planets and the pressure of solar radiation. The stream becomes more diffuse. The shower spreads out to last weeks, instead of days or hours, and the radiant becomes spread over a large area of the sky. The hourly rate of meteors gradually falls. In time the stream disappears entirely.

On any given night you'll see as many as 12 to 15 meteors that you can't trace back to any particular known meteor shower radiant. These renegades are called sporadic meteors. Rather than totally random, the sporadics may be remnants of ancient meteor showers that have long since dispersed.

Streaks in the Night

The light from a meteor is produced by a combination of the intense heating of the dust particle and of the atoms and molecules of the atmosphere around it. The passage of the high-speed particle creates a channel of hot ionized air that can be several meters wide. The streak you see is light from this glowing air channel as well as from the hot meteor itself.

Some very bright meteors shine



THE YEAR'S BEST SHOWERS

Shower	Peak Date	Meteors per hour	Speed per Hour (km/sec)
Quadrantids	January 3	40	41
Lyrids	April 22	15	48
Eta Aquarids	May 5	20	65
S. Delta Aquarids	July 30	20	41
N. Delta Aquarids	August 12	2–5	42
Perseids	August 12	40–100	60
Orionids	October 21–25	25	66
S. Taurids	November 3	15	28
Leonids	November 18	15	71
Geminids	December 14	75	35
Ursids	December 23	5	34

Data from *Observe Meteors* by David Levy and Stephen Edberg.

with distinct colors. They sometimes glow with the orange-yellow wavelength of sodium, the brilliant green of magnesium, and other colors produced by the presence of iron, calcium, and some less-common elements in the meteor particle.

The visible trail of most naked-eye meteors occurs at an altitude of 50 to 70 miles, well above the densest part of our atmosphere. Faint telescopic meteors are made of smaller particles that burn up even higher, perhaps 80 to 100 miles. Very bright meteors are larger and penetrate farther before starting to glow. However, even these burn out some 30 miles above the surface of Earth, an altitude at the upper reaches of the stratosphere.

A meteor's brightness depends on the particle's mass, composition, entry velocity, and angle. Particles weighing less than a gram may produce a streak no brighter than magnitude +4, just visible to the naked eye. A one gram meteor may flare to magnitude 0, equal to a bright star. It will take an object weighing 25 to 30 grams (about one ounce) to produce a spectacular meteor as bright as Venus at magnitude –4.

Some meteors, especially the brightest ones, leave glowing trains of luminous smoke. The meteor itself may last only a second, but the train can linger for a few seconds longer or remain glowing for several minutes as it gradually becomes distorted and dispersed by high-altitude winds.

A meteor brighter than magnitude –4 is called a fireball (or bolide if it appears to explode at the end of its path). While you may see one or two of these during a good night of Perseid watching, only one meteor in a million is large enough to survive its atmospheric plunge and reach the ground. In fact, there has never been a recorded case of a meteor shower member impacting Earth. Since shower meteors are comet-stuff, they are thought to be too dusty and fragile to survive the flight through the atmosphere.

No-Cost Astronomy

Meteor observing requires no telescope, costs next to nothing, and is simple, relaxing, and rewarding, even if you do have to stay up after midnight! You can watch meteors by yourself or with a group. It makes for a great summertime family activity. And it offers you a chance to make a contribution to the astronomical community.

Careful counts of meteors can help track how a shower's density and date of peak activity change over the years. These in turn provide information about the evolution of meteor streams and their association with comets and asteroids, thought to be the most primitive objects in the solar system.

To be useful, meteor counts should record the time and magnitude of each meteor and whether it was a shower member or a sporadic. Times can be recorded manually (in a group it's best to have someone assigned to this task), or by using a tape recorder to pick up the sounds of WWV or WWVH time signals from a shortwave radio (at 5, 10, 15, or 20 MHz), along with the voices of observers.

A couple of decades ago the American Meteor Society was the place to turn for instructions on how to conduct an organized meteor-watching session. Today the AMS receives data from a few skilled observers but hasn't the resources to educate beginners. With the AMS now unable to assist newcomers, I recommend those interested in meteors contact amateurs Karl and Wanda Simmons. They publish *Meteor News*, an excellent publication available by subscription. Write to them at Rte. 3, Box 1062, Callahan, FL 32011. Include a self-addressed stamped envelope.

Another good source of information for those serious about meteor observing is *Observe Meteors*, a book by David Levy and Stephen Edberg and available for $5.75 from Astronomical League Sales, 4 Klopfer Street, Pittsburgh, PA 15209, (412) 821-2681.

In Europe a new society for meteor observers has emerged. The International Meteor Organization (IMO) was founded by members of the Belgian astronomical community with the aim of instituting a worldwide visual and photographic patrol network. Its *Handbook for Visual Meteor Observation* (in English) is perhaps the best guide available, providing standardized forms and procedures. All data submitted on these regulation forms are entered into a computerized database.

Interested North American observers are encouraged to contact the IMO's North American coordinator, Peter Brown, at 181 Sifton Avenue, Fort McMurray, Alberta, Canada T9H 4V7, for additional information.

There you have it. With little more than a comfortable lawn chair, a watch, and a sheet of paper you can make truly useful meteor observations. Conducted as a group effort, an organized meteor watch can be a lot of fun.

But don't feel you need to get organized to enjoy the Perseids. All you really need to do is get outside. August 11 and 12 are good nights to do just that. Grab a lawn chair, a friend, and a warm blanket, then lie back and enjoy the summer night sky and the unique late show of this year's Perseid meteor shower. ☐

Christopher E. Spratt is a Canadian amateur astronomer with a special interest in meteors and meteorites. His last article for ASTRONOMY *was "It Came From Outer Space" in February 1991.*

A PUZZLING COMET

Do you want to observe a frequent visitor with several curious qualities? Step outside to see Comet Machholz this month.

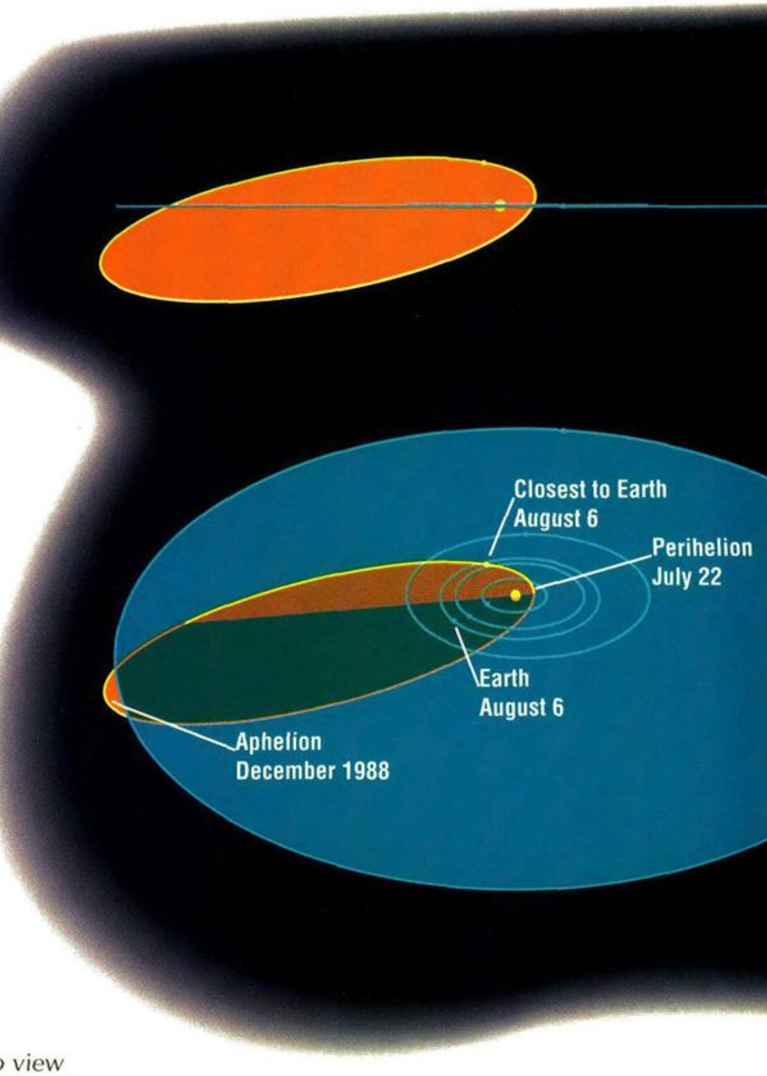
by Richard Talcott

This month features a spectacular display of the Perseid meteor shower and the bright planet Saturn dominating the evening sky. So it may be hard to work up a lot of enthusiasm for a relatively dim comet. That would be a mistake. For when Comet Machholz comes streaking by Earth in early August, observers throughout the Northern Hemisphere have a chance to see one of the most unusual comets known.

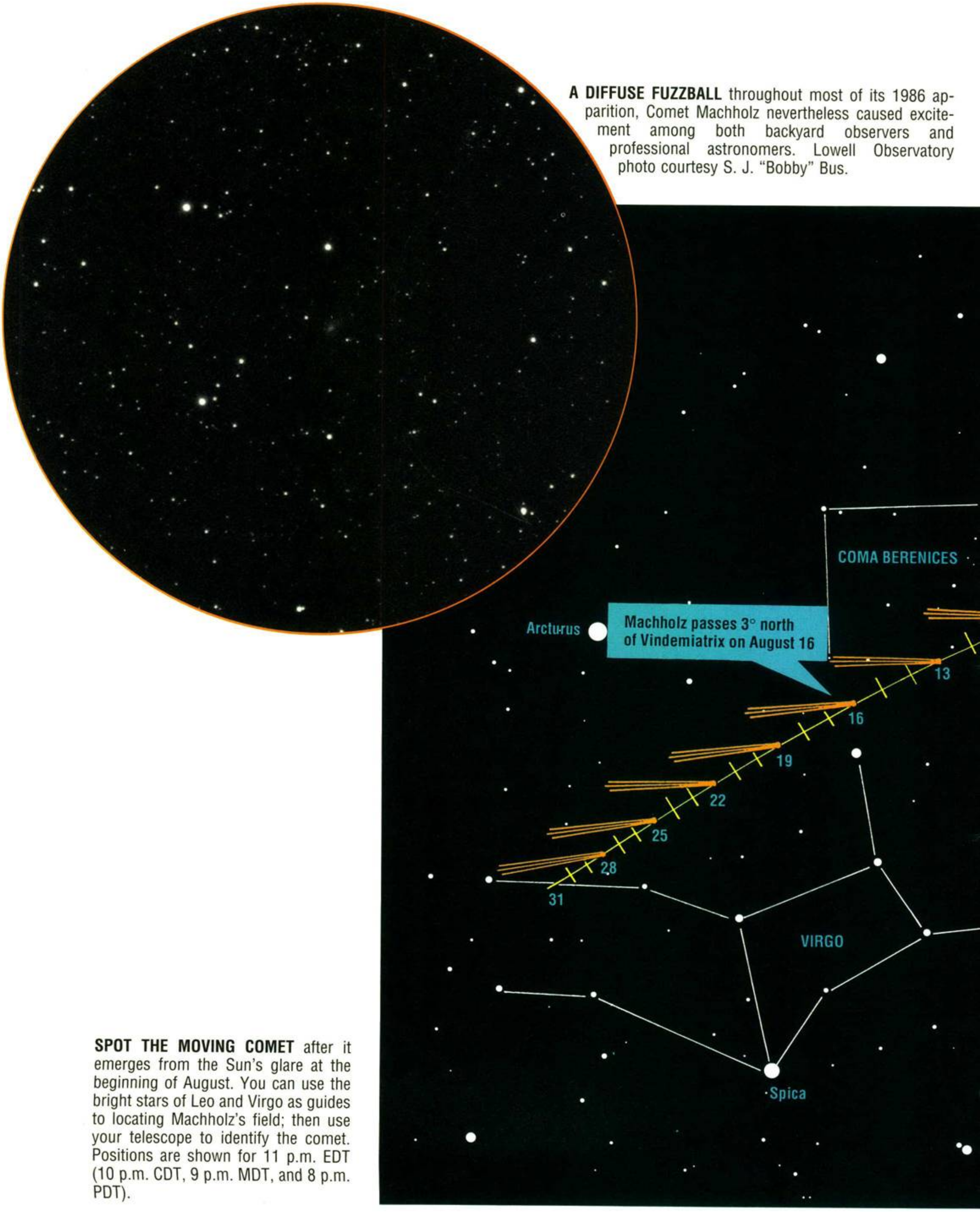
When Don Machholz, an amateur astronomer from San Jose, California, discovered the comet in May 1986, he had little inkling that it would turn out to be special. But when astronomers finally got enough observations to calculate an accurate orbit for the comet, they realized this was no ordinary beast. Each time Comet Machholz invades the inner solar system, it plunges to within 0.126 astronomical units of the Sun — the smallest perihelion distance of any short-period comet. At the opposite end of its highly elongated orbit, Machholz travels through the cold depths of space beyond the orbit of Jupiter. But it doesn't stay out there for long: the comet completes one trip around the Sun in a little over five years. (A final orbital oddity finds Machholz's orbit inclined 60° to Earth's orbit, an extremely high value.)

Five years have now passed since the comet's last apparition, so Machholz is poised to return to our sky. It first came within range of amateur scopes in late June, but it was then buried deep in the southern sky and all but invisible from mid-northern latitudes. This situation changes for the better, however, after the comet passes perihelion on July 22.

By the first week of August, Machholz comes into view low in the west-northwest after sunset. On the 1st, it lies about 10° above the horizon when nautical twilight ends as seen from 40° north latitude and is expected to shine at 9th or 10th magnitude. You should be able to pick it out with a good pair of binoculars or a small telescope. Look for a small, fuzzy patch of light among the background stars of northern Leo. (The map below will



THE STRANGE ORBIT of Comet Machholz (a small perihelion distance, large eccentricity, high inclination, and short period) makes this comet an unusual one.

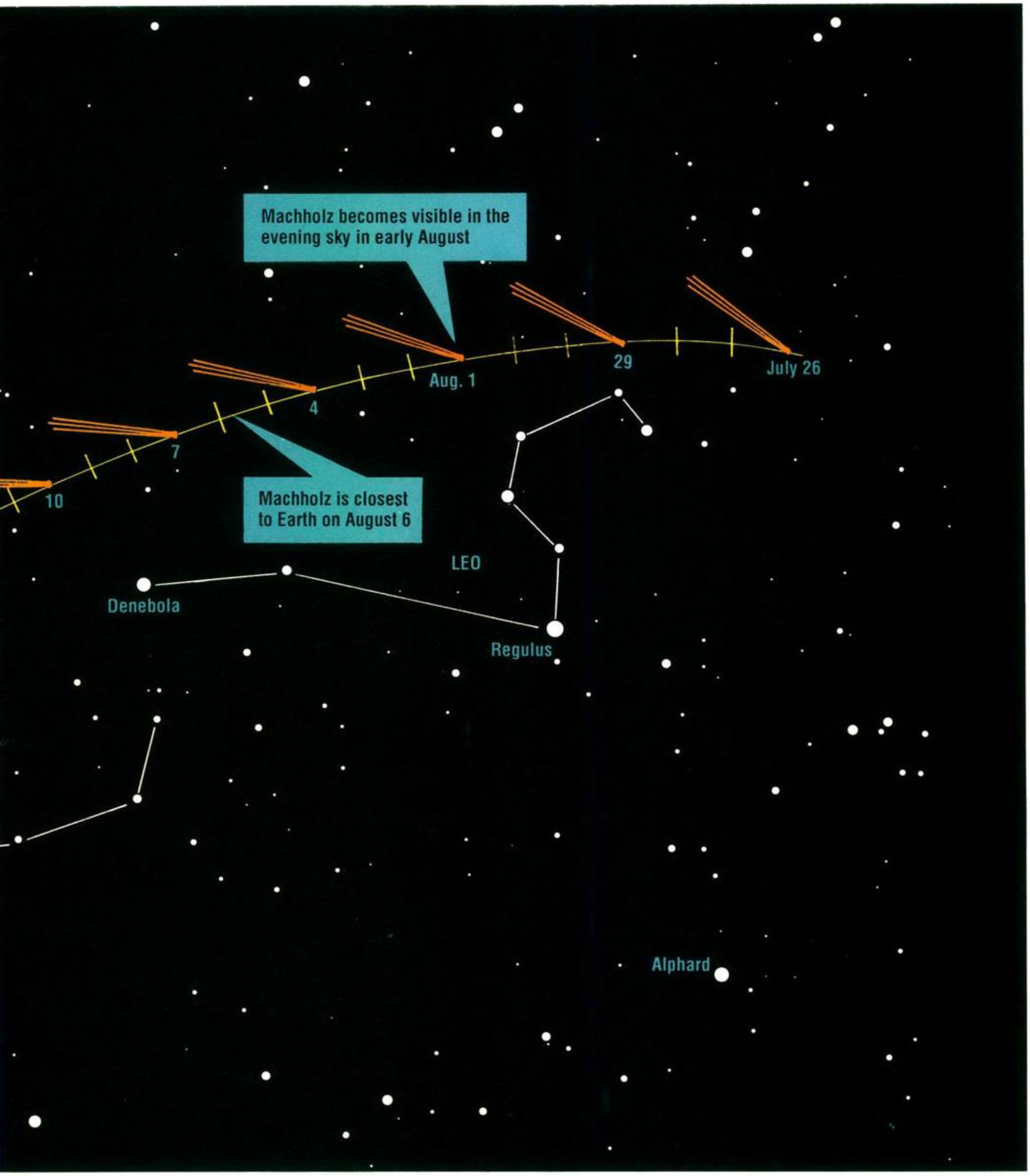

COMA BERENICES
Arcturus
Machholz passes 3° north of Vindemiatrix on August 16
13
16
19
22
25
28
31
VIRGO
Spica

A DIFFUSE FUZZBALL throughout most of its 1986 apparition, Comet Machholz nevertheless caused excitement among both backyard observers and professional astronomers. Lowell Observatory photo courtesy S. J. "Bobby" Bus.

SPOT THE MOVING COMET after it emerges from the Sun's glare at the beginning of August. You can use the bright stars of Leo and Virgo as guides to locating Machholz's field; then use your telescope to identify the comet. Positions are shown for 11 p.m. EDT (10 p.m. CDT, 9 p.m. MDT, and 8 p.m. PDT).

get you to the right area of sky; also see Through the Eyepiece on page 49 for more information.) You may also see a short tail pointing away from the Sun — in the same direction as the tails shown below, but probably not as long.

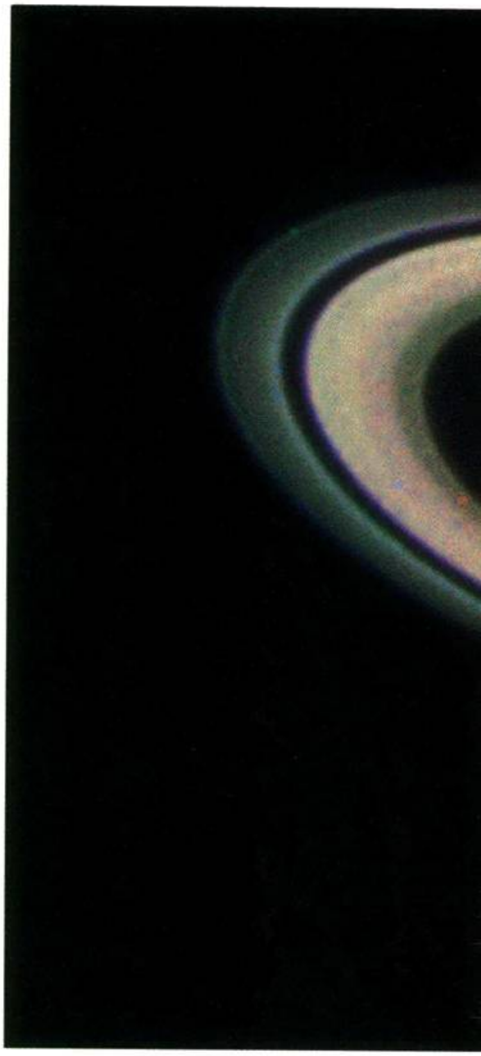
The first ten days of August are the best time to view Machholz because the comet is reasonably bright, it climbs higher in the sky with each passing day, and the Moon is absent from the evening sky. Once the Moon starts brightening around mid-August, Machholz will be washed out until the tail end of the month. By then the comet lies in Virgo and you'll need at least a 10-inch telescope to spot the 14th-magnitude fuzzball. At that point Machholz will be but a memory to most of us — a treasured memory gained from seeing one of the solar system's most remarkable members. ☐


Machholz becomes visible in the evening sky in early August
July 26
29
Aug. 1
4
7
10
Machholz is closest to Earth on August 6
LEO
Denebola
Regulus
Alphard

Saturn, Lord of the Rings

Saturn, the solar system's loveliest sight, is now placed perfectly for viewing during the evening hours.

by Robert Burnham



No other celestial object compares with Saturn. Small, jewel-like, and unbelievably perfect, Saturn in a telescope is astronomy at its best. Show it to people and you'll always hear a gasp of delight when they look in the eyepiece.

This year Saturn lies in the zodiacal constellation of Capricornus, the Sea Goat, a dim starry figure in the shape of a wide shield. Saturn is easy to find because of its brightness, which is magnitude 0.3 on July 1. Look for an ivory-white "star" low in the southeast as twilight deepens. On the night when Saturn lies opposite the Sun in the sky (July 26/27), the Full Moon will pass about 2° north of it, brightening the sky and blanketing Saturn's light with its own.

Even small telescopes at low magnification (30x or so) can show you the rings, but a larger instrument and higher powers will reveal much more. No matter what size telescope you have, however, taking a few steps to help it perform at its best will make your Saturn-watching far more enjoyable.

Setting Up

Experienced observers know they must roll their telescopes outdoors right after sunset. Telescopes need time to adjust to match the air temperature. If they don't, temperature differences will set air currents moving around the instrument, generating bad "seeing" that distorts views.

Bad seeing can come from surroundings, too. Unlike galaxies and nebulae, where an inky black sky is all-important, planets are forgiving of light pollution. But it is worth the trouble to place the instrument where you can view Saturn over shrubs, trees, or an open, grassy field. Viewing across parking lots or over rooftops will be like looking across a warm stove; the heat waves they give off will keep views blurry far into the night.

If you have an equatorial mounting, spend a few minutes to align it on the pole and run a power cord to the clock drive. Don't ignore creature comforts either: Saturn's –20° declination means you can sit at ease on a chair or stool while you give the planet the long looks it deserves. A folding table will keep eyepieces, filters, and a notebook right at hand.

Beginners are often tempted to use as much magnification as their eyepieces permit. But unless the seeing is supremely still, you'll find that lowering the magnification a little gives more pleasing views. Lower powers are also less demanding of optical quality and mounting stability. The trick is to find whatever magnification lets you relax and essentially ignore the instrument.

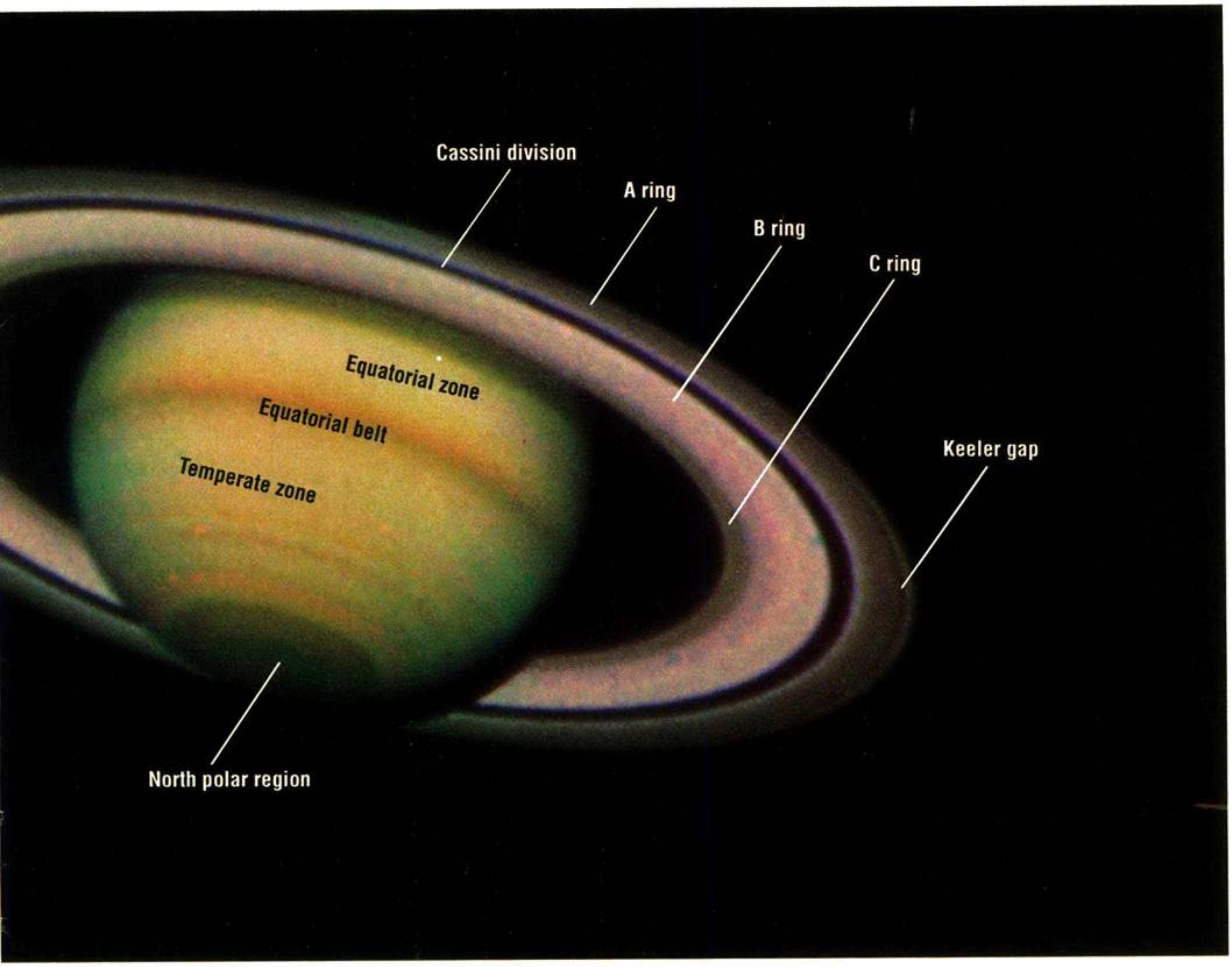
Belts, Zones, Winds

Saturn the planet is a ball of hydrogen 120,700 kilometers across at the equator; Saturn the telescopic object spans 18" equatorially, about half Jupiter's apparent size. The rings, which in reality are 272,700 kilometers in diameter, reach 42" across in your eyepiece. At present the planet's north pole is tipped 25° toward us, although the tilt lessens each year and we will see less and less of the rings' north side until they are edge-on in 1995.

Settle down with your scope, give the focus a last touch, and let your imagination roam out to that distant world. At first, the disk of Saturn looks all but featureless. But as your eyes grow used to it, you'll see several markings. (See photo above.) The dark belts and light zones are enormous streaks of cloud, made of ammonia and colored by hydrocarbons. They lie at the top of Saturn's atmosphere, which is thousands of kilometers deep. The equatorial zone, where the winds blow eastward at more than 1,300 kilometers an hour, is light-colored and flanked by the dark north and south equatorial belts. Farther away from the equator are the north and south temperate zones, lighter than the equatorial belts but streaked by the varying thin dark temperate belts. The polar regions are generally dark.

Lying deeper in Saturn's atmosphere, its features are not as prominent as Jupiter's. But in months to come, if you start viewing before twilight is gone, the luminous sky around the planet will reduce its dazzle and reveal the subtle features more readily.

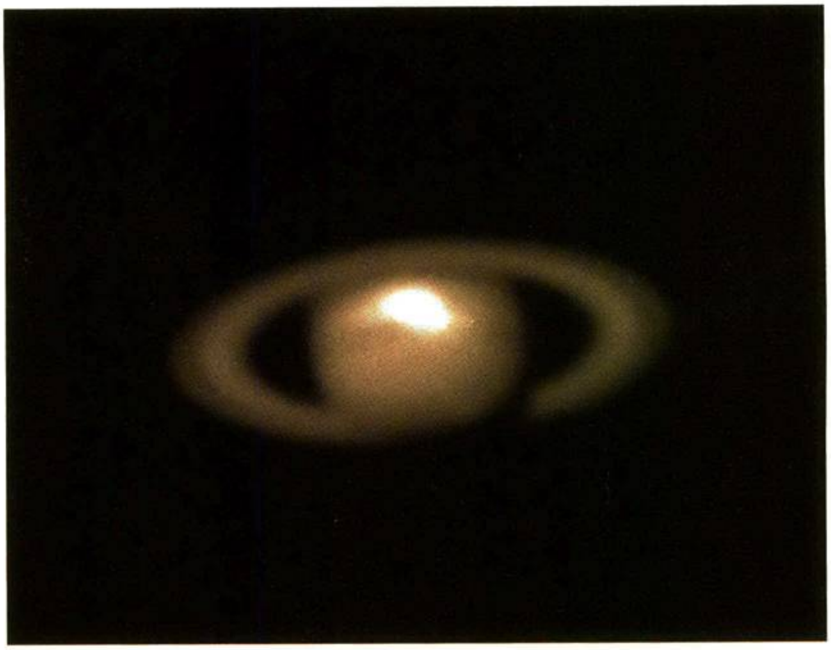
Veteran Saturn watchers often reach for a filter when they want to make features more visible. Holding a *light-blue filter* (such as a Kodak Wratten 80A or 82A) over the eyepiece darkens the belts (which are



LIKE SOME GIANT'S TOY, Saturn and its rings glide silently through the night sky. This shot from the Space Telescope shows dark belts and light zones visible in a backyard telescope. (This photo and all others have south at top.)

slightly reddish). A red filter (23A) will darken the polar regions, which often have a bluish hood over them. Alternate the filtered view with the unfiltered. Notice changes?

Saturnian white spots are small and fairly rare, and occur mainly in the equatorial regions. Lasting typically just a few weeks, they have diameters of only a few seconds of arc and are seen best at medium or high power. One outstanding exception was the Great White Spot that erupted at Saturn's equator last autumn. (See "Tracking the Great White" in the March 1991 issue.) Just what triggered this gigantic ammonia cloud eruption is a mystery, but it appears to be a seasonal effect, occurring at roughly 30-year intervals in the northern hemisphere's midsummer.



A HUGE STORM OF AMMONIA erupted near Saturn's equator last autumn, creating a Great White Spot that lasted for several weeks. Its eruption was discovered by backyard astronomers. Photo by Don Parker, October 4, 1990.

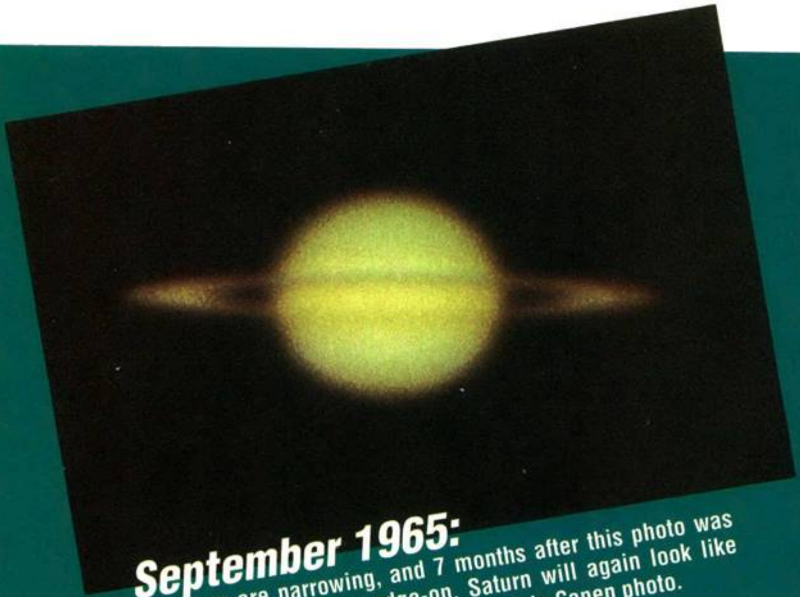
While the Spot has dissipated, this phenomenon is far from understood and wise observers will keep a sharp eye open for future disturbances.

Ringworlds

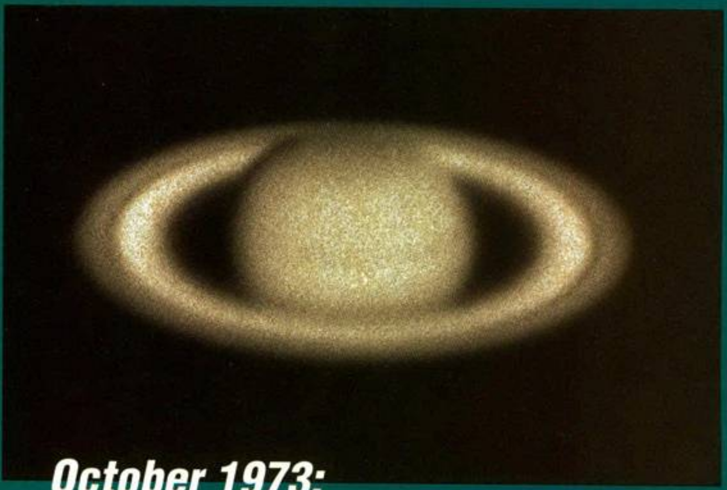
Traditionally, Saturn displays three rings to observers on Earth. The outermost is the off-white A ring, 15,200 kilometers broad. About $^{1}/_{5}$th the way in from its edge is the narrow Keeler (or Encke) gap, which poses a test of optics and seeing for medium-sized instruments. Inside the A ring is a dark band, the 3,500-km-wide Cassini division. Look carefully where it crosses the disk and you may see Saturn shining *through* the gap. The widest ring is the bright bluish-white B ring, which extends inward from the Cassini division a distance of 25,300 kilometers. At its inner edge is the dusky C (or crepe) ring. Thin and tenuous, the C ring is difficult to see in scopes under about 8 inches' aperture. (Hint: compare the view where it stands in front of Saturn's disk with that just beside the disk.) The C ring is 19,000 kilometers wide and stops 12,900 kilometers above the racing cloud tops.

But the Voyager spacecraft changed this simple picture forever. The broad rings turn out to be made of thousands of thin ringlets, the Cassini division has material orbiting in it, and there are enough ring particles in other places to add outer rings E, F, and G, plus an inner D ring!

These new rings are invisible from Earth or require professional instruments to see. But for a long time sharp-eyed observers on Earth had noted faint radial lines on the B ring's eastern side, where orbiting ring particles emerge from behind Saturn into daylight. Voyager confirmed the existence of these "spokes," finding that they consist of particles the size of cigarette smoke and appear to be controlled by Saturn's magnetic field.



September 1965:
The rings are narrowing, and 7 months after this photo was taken, they were seen edge-on. Saturn will again look like this in October 1994. Charles and Virginia Capen photo.



October 1973:
Now the rings are fully open; the south side tips 27° toward Earth. E. Ken Owen photo.

Moons without End?

Saturn's family of moons has 17 named members and if the anonymous ring particles are included, innumerable others. Two of these moons are easy to spot in backyard telescopes. The largest is Titan, 5,200 kilometers in diameter. If Titan didn't belong to Saturn, it could be a small planet on its own — it is slightly larger than Mercury and has a nitrogen atmosphere denser than Earth's.

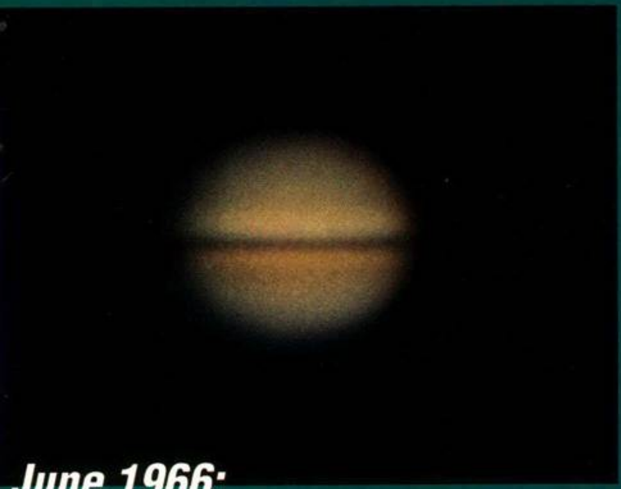
Shining at 8th magnitude, Titan is visible even in binoculars. With a large scope and perfect seeing, high magnifications will show you Titan's disk. The moon circles Saturn every 15d 22h 41m; in August it will lie 20 Saturn radii west of the planet on the 2nd and 18th and the same distance east on the 10th and 26th.

The other easy moon to look for is Rhea, which shines at 10th magnitude. Rhea, however, is only 1,500 kilometers in diameter. What makes it so conspicuous then? Titan's atmosphere is darkened by photochemical smog and reflects only about 20 percent of the light falling on it. Rhea, on the other hand, has an exposed, heavily cratered surface of ice and frost that reflects 70 percent — as much as fresh-fallen snow on Earth. Rhea orbits once every 4d 12h 25m at a distance of 8.7 Saturn radii from the planet's center.

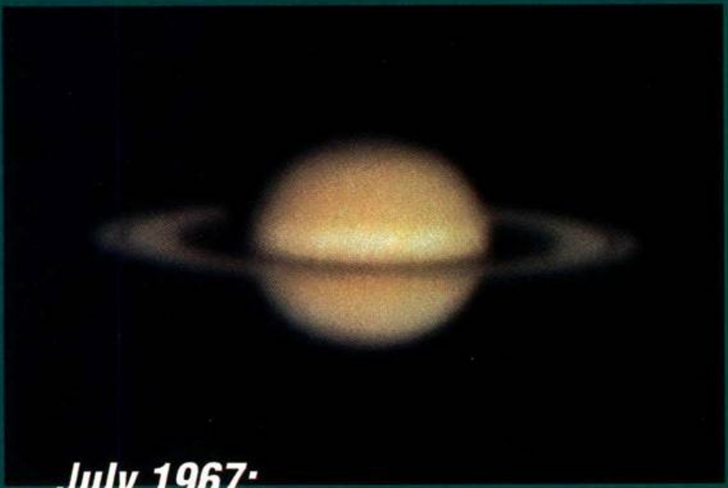
One more moon is definitely worth knowing: Iapetus, famous for shining at 9.4 magnitude when it lies west of Saturn and 11.1 magnitude on the eastern side. What causes this 5-fold difference is that the leading hemisphere of Iapetus (seen when it lies east of Saturn) is as dark as tar. Its trailing hemisphere, however, is almost as white as Rhea. Scientists

THE EVER-VARYING RING

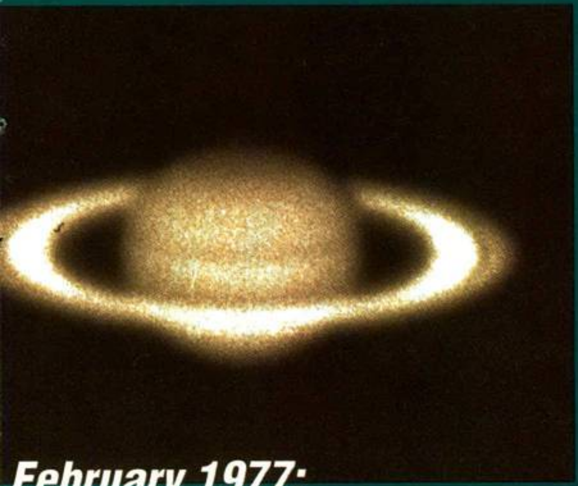
Saturn's axis tilts like Earth's, so as we look out toward it at different times during Saturn's 30-year orbit, we see its rings variously open or closed.



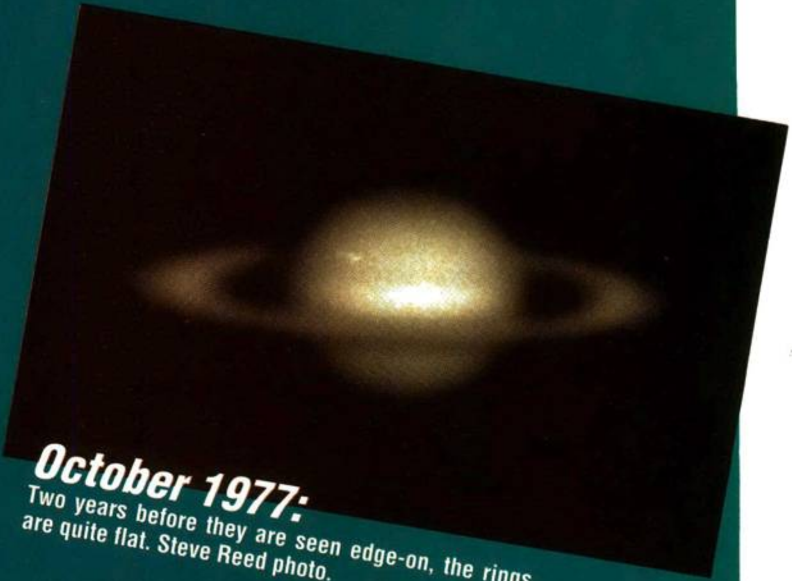
June 1966:
Seen edge-on, the rings have disappeared. Note how oval Saturn is! Charles Capen photo.



July 1967:
Opening up again, the southern face of the rings still appears narrow, but the Cassini division is just visible. Charles Capen photo.



February 1977:
Noticeably narrower, the rings are closing once more. Thomas Rotkiewicz photo.



October 1977:
Two years before they are seen edge-on, the rings are quite flat. Steve Reed photo.

think that Iapetus' leading hemisphere may have swept up the dark dust ejected from another moon, Phoebe, by meteorite impacts. Look for Iapetus west of Saturn on July 13 and east of it on August 20.

Why Hurry the Acquaintance?

The best way to enjoy Saturn is to spend time just looking at it. I guarantee that by the end of a week's observing, you'll be noticing things you just didn't see when you began. You have an invaluable edge on professional Saturn astronomers, who can't spend the many nights you can gaining familiarity with the planet's subtly varying moods. And you can bet your bottom dollar that when Saturn erupts with another Great White Spot, it'll be some backyard astronomer like yourself who spots it first.

Longtime observers often find that some particular view of a planet becomes their most memorable. One such Saturn from many years ago lingers in my memory. At the end of a crystal-clear night spent exploring both it and other sights, I was watching the planet fade in the eyepiece as dawn brightened. The birds were awake. Before the steadily brightening sky's blue washed them out, Saturn's delicate bands grew more visible and its ivory color seemed to deepen minute by minute.

The telescope tube and every surface around was soaking wet with dew, but I couldn't let go of the view. It was simply too beautiful. Finally, just before closing up the scope, I looked away and saw sunlight coloring the highest treetops nearby with the same pale gold Saturn was showing.

That morning gave me the Saturn I'll remember forever. Maybe you'll see yours this summer. □

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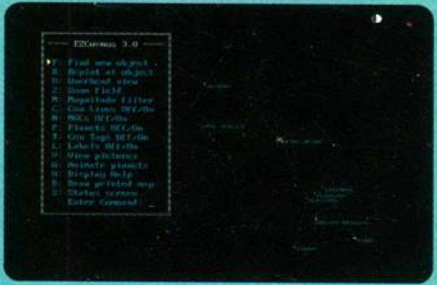

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NIGHT OF THE AURORA

On the night of March 23/24, 1991, a brilliant aurora blazed across the sky and was witnessed in towns and cities around the world. Sparked by a large solar flare a day since, the aurora covered most of the sky and was unusually active, transforming from curtains to sheets to spikes in front of the bedazzled eyes of many observers. ASTRONOMY received dozens of submissions from astrophotographers, all of whom captured the aurora's strongly ruddy appearance.

"It was the best display up here in over a year, and was easily comparable to the great aurorae of March and October 1989," says Scott Neilsen of Superior, Wisconsin. Although a First Quarter Moon lay relatively near the center of auroral activity, Neilsen captured the height of activity on film with a battery of 15mm, 24mm, and 35mm lenses.

Observations of the aurora weren't limited to the northern United States, however. Vic Winter of the Astronomical Society of Kansas City was in the midst of a club observing session when he spotted auroral activity. "A small group of observers had gathered at our dark sky site about 65 miles southwest of Kansas City, and we planned to test out some CCD cameras. As we waited for two club members to bring a laptop computer, we noticed a peculiar, faint glow in the northwest. Within five minutes the sky was ablaze with color and everyone scrambled for conventional cameras and films — the CCDs had to wait one more night!"

At first Winter and his colleagues didn't suspect such a prolonged show. "We were pleasantly surprised. The first outburst began at about 11:45 p.m. and lasted nearly 45 minutes. Many spikes of light became visible and at times one clearly cut through Polaris and extended at least 10° higher in the sky. The overall color seemed reddish and orange, but the spikes at times appeared bluish. At times the aurora covered the entire northern horizon and extended far up into the sky. It was stunningly bright and full of detail, and it was a night we won't soon forget." — *David J. Eicher*

THE SKY LIT UP on the night of March 23/24, 1991, when observers around the globe reported brilliant auroral displays. Spectacular photos were sent by Scott Neilsen of Superior, Wisconsin (right); Franklin B. Morgan of Nichols, South Carolina (above right); and Vic Winter, of Parker, Kansas (above).

THE RED RAYS OF THE ROSETTE

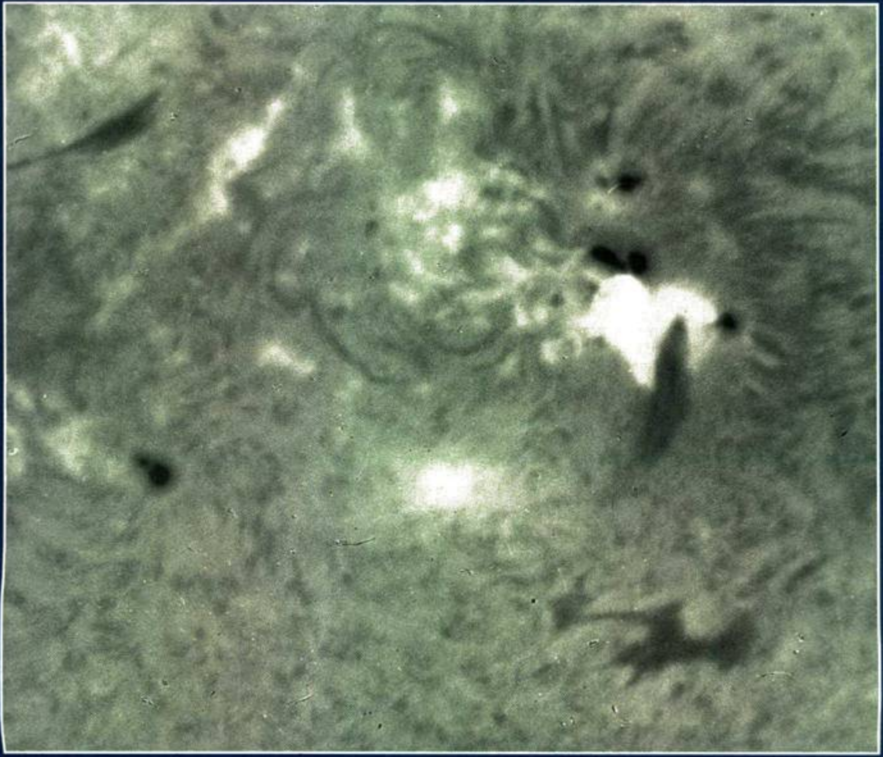
Laced wih intricate webs of nebulosity that surround a bright cluster of young stars, the Rosette Nebula in Monoceros is surpassed in beauty by few deep-sky objects. Gerard Rhemann's photograph of the Rosette (opposite page) nets this month's $100 "Best Astrophoto" award. Rhemann used a Takahashi ε-160 telescope, hypersensitized Fujicolor Super HG 400 film, and composite printed two negatives (15- and 20-minute exposures) taken from dark skies outside of Vienna, Austria.

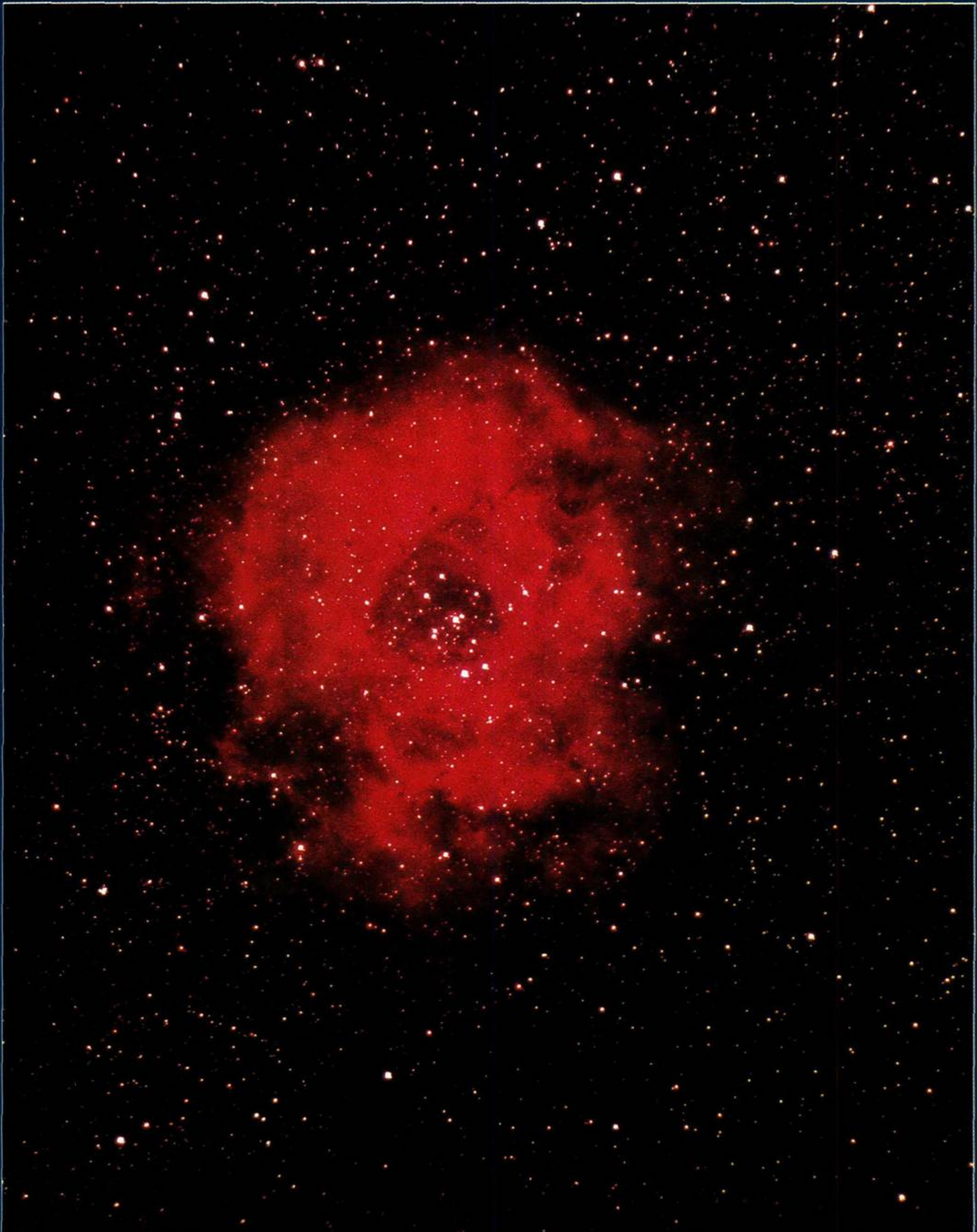
Not so familiar an object is Nova Herculis 1991, captured on film by Ronald E. Royer and marked by an arrow (below right, center). This galactic interloper appeared suddenly in late March 1991 and briefly reached naked-eye visibility before fading.

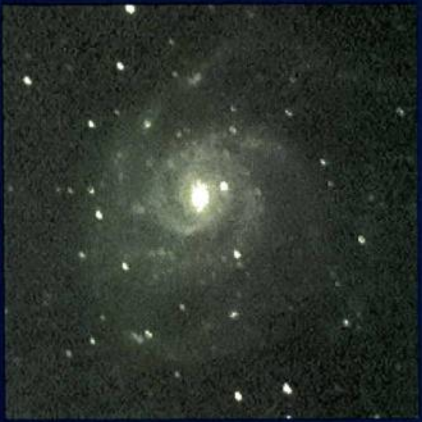
Other cosmic surprises last spring included a powerful flare on the Sun captured in detail in Frank Melillo's hydrogen-alpha photo (bottom left). Melillo used an 8-inch SCT at f/30, a 0.6Å H-alpha filter, and a 1/4-second exposure on Tech Pan film.

At Florida's Winter Star Party, astrophotographer Lester F. Shalloway recorded a prominence extending high above the Sun's surface (bottom right). Shalloway recorded the image on video with an Astro Physics refractor and a Panasonic WVD5100 camera and photographed this image off a television screen.

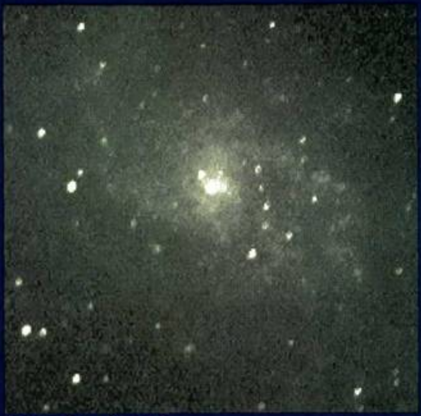
The greatest surprise in Bob Crews' recent memory came as he photographed Orion using a camera fixed on a tripod and captured a magnitude –5 fireball on February 9, 1991 (top left). Two days later John Knapp recorded an exquisite Jupiter image with the 31-inch telescope at Warren Rupp Observatory near Columbus, Ohio (left).







M101 4-inch @ f/4



M33 4-inch @ f/4

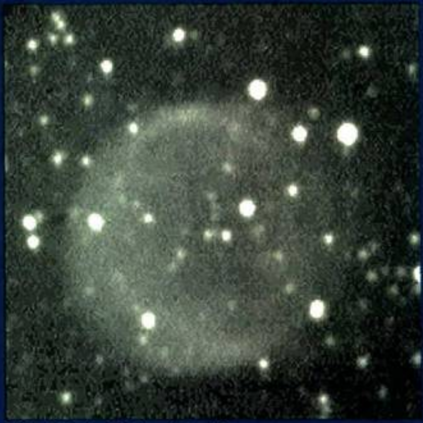
THE MAGIC OF CCDs

CCDs are revolutionizing the way amateur astronomers capture images of the sky. With a simple chip, a telescope, and a computer, you can manipulate short-exposure images to bring out details that match observatory shots of several years ago.

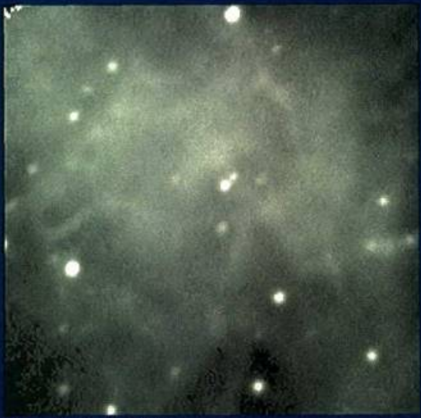
The images on this page were made with telescopes small and large. Forest Hart's CCD images (M101, M33, M97, NGC 3628, M82, and M64) were made with a 4-inch f/4 reflector and a SpectraSource Lynxx-PC CCD camera. Exposure times ranged from 5 minutes to 15 minutes.

Using a substantially larger instrument — a 25-inch f/5 reflector — Canadian astrophotographer Jack Newton produced the images of NGC 6781, M1, M57, and NGC 6207. Newton used an SBIG ST-4 CCD camera and exposures ranging from 4 to 6 minutes.

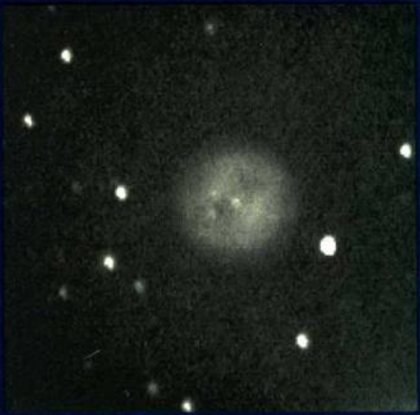
All images were processed with Richard Berry's Astro IP software and were prepared for publication in ASTRONOMY using Adobe Photoshop.



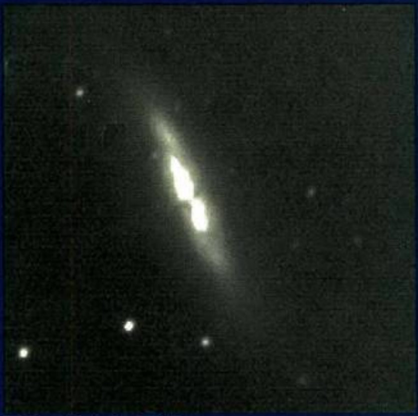
NGC 6781 25-inch @ f/5



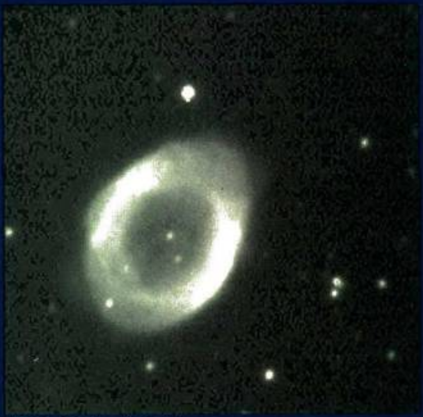
M1 25-inch @ f/5



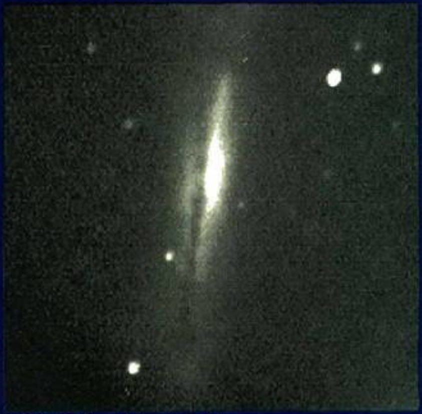
M97 10-inch @ f/5



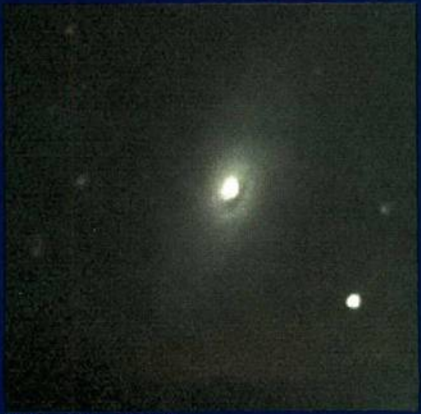
M82 10-inch @ f/5



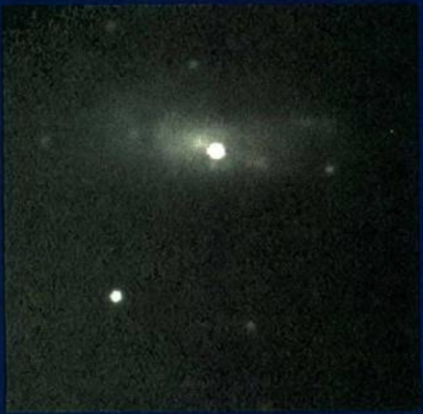
M57 25-inch @ f/5



NGC 3628 10-inch @ f/5



M64 10-inch @ f/5



NGC 6207 25-inch @ f/5

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The Observer's Sky Atlas, by Erich Karkoschka, (Springer-Verlag, 1990), ISBN 0-387-51588-7, 130 pages, sewn binding, acid-free paper, paperback, $14.95.

If you're looking for the perfect little star atlas to pop into your pocket and take out on a night's observing session, this is it. *The Observer's Sky Atlas* has 50 charts that show bright stars and many deep-sky objects across the entire sky and contains numerous inset maps showing in detail regions of particular interest. All of this fits into a book measuring 5 by 7.5 inches, making it the most informative little sky guide in the business.

Originally published in German in 1988, this book was issued in an English-language edition two years later by Springer-Verlag's New York office. The book opens with a brief introduction to astronomical catalogs, atlases, and data, including all of the standard information typically thrown at newcomers — magnitudes, sidereal time, celestial coordinates, directions in the sky, and so on. The introduction is competently done if a little stiff, but this may be due in part to the translation.

The guts of the book is made up of the 50 star charts. Throughout this section each left-hand page lists basic data for interesting objects shown on the maps on the right-hand pages. The maps are attractively done in black and white and various shades of gray. This allowed the author to in some cases stack several inset maps on top of each other and to maintain the usefulness of the charts under red light. Although not as spectacular as some modern star maps, the charts are perfectly utilitarian. They show naked-eye stars, and the insets depicting deep-sky objects show enough stars to locate galaxies and nebulae — even those in a crowded star field — with binoculars or a small telescope.

How does it compare to Wil Tirion and Ian Ridpath's little book *The Night Sky* (Collins, 1985)? Both cover the whole sky. But Karkoschka's book is physically larger and has fewer pages, while its charts go fainter and the text lists much more data about more objects. If forced to draw a distinction, you could say, rather arbitrarily, that Tirion and Ridpath's book is for binocular users and this one's for small telescope owners.

If *The Observer's Sky Atlas* has a drawback, it's the price. Springer-Verlag has priced this book at a hefty $14.95, which seems like a lot for a small paperback. However, you're paying for the information here, and if you're looking for a friendly little companion to ride along in a jacket and always be ready to provide directions to your favorite objects, this book may be for you. — *David J. Eicher*

The Solar System

Small Worlds, by Joseph W. Kelch, (Julian Messner, 1991), ISBN 0-671-70013-8, 155 pages, hardcover, $13.35.

This is a book, nominally aimed at children or young adults, which many fully grown backyard astronomers might want to own. Subtitled *Exploring the 60 Moons of Our Solar System,* it presents the varied array of satellites that space probes have shown us. Arranged in solar system order (Earth to Pluto), it illustrates each moon with at least one photo. The accompanying text describes the environment of each planet and what this has done to the moons orbiting there. The last twenty pages present a checklist of moons, giving their date of discovery, diameter, mass (relative to Earth's Moon), surface gravity, albedo, and so on. This is a very nice work.

General Astronomy

The Astronomers, by Donald Goldsmith, (St. Martin's Press, 1991), ISBN 0-312-05380-0, 332 pages, hardcover, $24.95.

This is the companion book to the PBS TV series that aired last spring. Its chapters generally follow the same sequence as the shows — although the book works quite well on its own as a general survey of modern astronomy. The presentation is aimed at the general reader. It is thin on color illustrations compared to such classic "TV books" as *The Ascent of Man* and *Civilization,* but the text is engagingly written.

Clyde Tombaugh, by David H. Levy, (University of Arizona Press, 1991), ISBN 0-8165-1148-9, 212 pages, hardcover, acid-free paper, sewn binding, no price given.

Clyde Tombaugh is known to every amateur astronomer as the person who discovered Pluto. What many do not know, however, is that he did a great many other things in astronomy, including discovering photographic evidence

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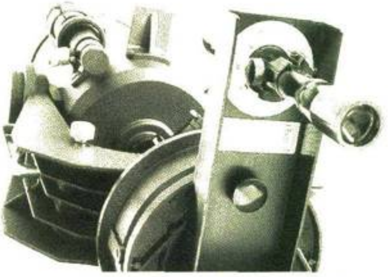

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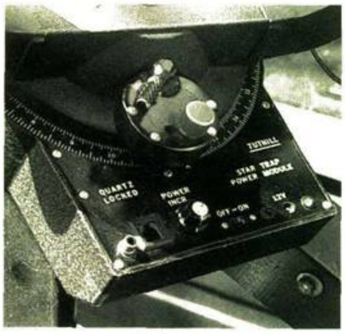

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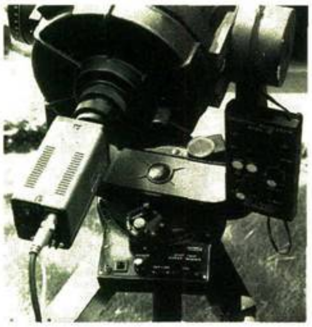

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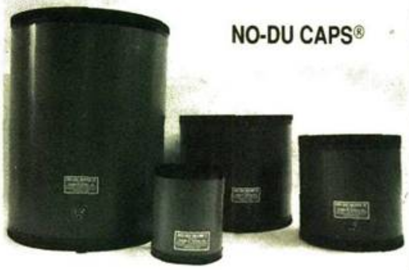

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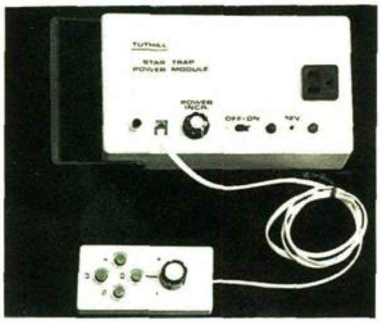

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for superclustering among galaxies (see March 1991 issue). David Levy has written a graceful and informative biography of a much-beloved contemporary astronomer.

Astronomy From A to Z, by Charles A. Schweighauser, (Illinois Issues, 1991), ISBN 0-9620873-5-1, 186 pages, paperback, $14.95.

Subtitled *A Dictionary of Celestial Objects and Ideas,* this book is less a dictionary than a mini-encyclopedia: it contains a little over a hundred short essays on various astronomical topics, arranged alphabetically. The author, a teacher of astronomy at Sangamon State University, has done a good job of presenting ideas clearly and defining terms for the general reader.

Astronomy on the Personal Computer, by Oliver Montenbruck and Thomas Pfleger, (Springer-Verlag, 1991), ISBN 0-387-52754-0, 255 pages, hardcover, acid-free paper, sewn binding, $49.50.

This book provides a useful set of programs that deal with topics in celestial mechanics and spherical astronomy: rise and set times, comet and planet orbits, solar eclipses, stellar occultations, astrometry, and the like. Nine programs in Turbo Pascal are provided on a $5^1/_4$-inch floppy disk tucked into a pocket inside the back cover.

ETs, Etc.

The SETI Factor, by Frank White, (Walker Publishing, 1990), ISBN 0-8027-1105-7, 250 pages, hardcover, $19.95.

The Search for ExtraTerrestrial Intelligence (SETI) may claim its greatest value by forcing us to rethink our views toward life, the universe, and ourselves. What would it mean if we never did contact anyone else? Or if we did? White does a good job of outlining the state of current research and offers projections about what's afoot in the next few years.

The Search for Extraterrestrial Intelligence, by Edward Ashpole, (Blandford Publishing, 1990), ISBN 0-7137-2210-X, 170 pages, paperback, sewn binding, $10.95.

Ashpole presents for the general reader a detailed look at the basis for life on Earth and assesses the chances of life occurring elsewhere in the universe. Besides describing the various passive searches that are going on, he also discusses ways that interstellar migration could be carried out. ☐

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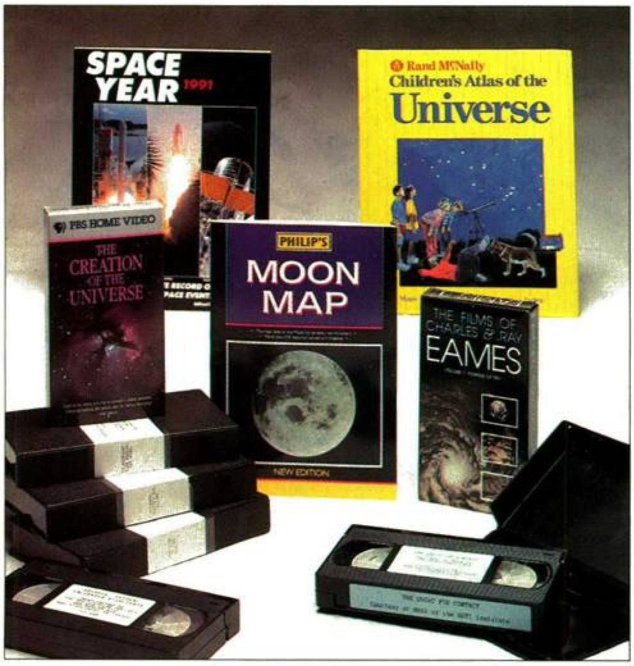
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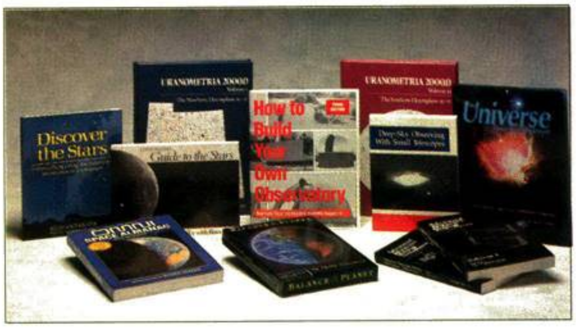

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PLANET SIMULATION SOFTWARE

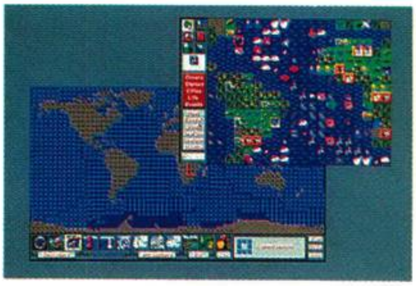
SimEarth, The Living Planet, *produced by Maxis Software, distributed by Brøderbund Software, 17 Paul Drive, San Rafael, CA 94903-2101, (800) 521-6263 or (415) 492-3200. $69.95. Versions available for both IBM and Macintosh computers (Mac version reviewed).*

What would happen if 100 atomic bombs were detonated in the Northern Hemisphere? If Earth were caught in the middle of an intense meteor swarm? If all the trees were cut down in North America? Or if dinosaurs made a startling reappearance? How could Mars or Venus be changed to make either of these planets a suitable place to live?

Answers to these fanciful questions are now possible with SimEarth, a program for IBM and Macintosh computers. This software is amazing: the color graphics are outstanding, the sound first-rate. A help function and a glossary are available on-line.

This software provides no less than a simulation of an entire history of Earth or a similar planet. It uses a holistic approach to understanding Earth, based on a very controversial theory called Gaia. As stated in the introduction to the 220-page manual that comes with SimEarth, the Gaia theory purports that the rocks, civilization, life on Earth, and the atmosphere and oceans are interrelated. James Lovelock, the originator of the Gaia theory, who assisted in the design of SimEarth and who wrote major sections of the manual, has suggested that most of Earth's systems are self-regulating. This regulation is expressed in SimEarth as interconnected feedback loops. Push one button or change one setting and a cascade of events follows, in much the same way the real Earth works. The difficulty is understanding how your interference or the occurrence of a natural event such as a meteor impact or great earthquake may change SimEarth's simulation.

You can begin a SimEarth session by selecting one of the preset startup scenarios, such as the end of the Cambrian Era, or by letting SimEarth present you with a random planet. If you choose the random-planet startup, then you must select one of four possible time scales: geologic (lasting billions of years), evolutionary (hundreds of millions of years), civilization (tens of thousands), or technological (centuries). From this point, SimEarth operates the same for a preset scenario or a random planet. You may either sit back and watch the world evolve on its own or choose to interfere.

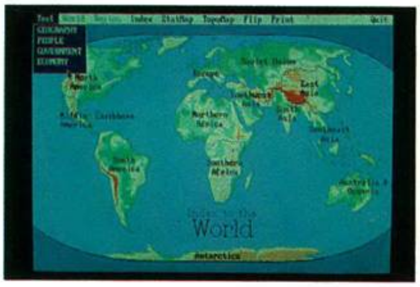


GOOD BUT COMPLEX GRAPHICS provide SimEarth users with a picture of how their planet is evolving.

You have many different means of interference. You can riddle the planet with fires, hurricanes, plagues, or other disasters, or if adequate energy sources are available, build plants to add oxygen, nitrogen, or carbon dioxide to the atmosphere. You can also introduce new species or change the distribution of ecosystems such as grasslands, forests, or shallow seas.

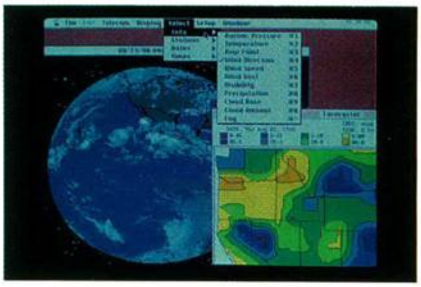
I spent an hour watching the first 4.5 billion years of evolution of an Earth-like planet. The evolutionary steps and the time scales were remarkably close to what scientists currently think happened on Earth. The simulation began near the end of the accretionary phase, when the last large meteorites were hitting my planet. After 200 million years, most of my planet was covered by lakes and small shallow seas. The first self-replicating molecules arose from the primordial soup after almost 2 billion years, followed shortly by development of the first single-cell forms of life. After a total elapse of 4.3 billion years, I pinpointed where the first animals walked onto land. After this remarkable event, evolution proceeded at a very fast pace.

The main drawback to SimEarth is that it is very complex to operate. The program has lots of windows, icons, buttons, options, and control panels. It requires patience to learn how to operate it and watch the results. This will deter many people from using SimEarth to full advantage. However, this program should find a home in classrooms. Instructors of earth, life, and social sciences should consider using SimEarth as part of their curriculum. —*John Dvorak*



The Software Toolworks World Atlas, *The Software Toolworks, 60 Leveroni Court, Novato, CA 94949, (415) 883-3000, FAX: (415) 883-3303. $59.95. For IBM-PC, PS/2, and compatible computers. CD-ROM version also available for $149.95.*

World Atlas provides over 240 EGA/VGA-quality color maps of the globe, including thematic, reference, and regional relief maps. Useful for astronomers planning eclipse expeditions or for the just plain curious, World Atlas also contains databases listing statistics for every country in the world in the categories of geography, people, government, economy, communications, defense forces, and travel. World Atlas supports a mouse and pull-down menus.



Accu-Weather Forecaster, *The Software Toolworks, 60 Leveroni Court, Novato, CA 94949, (415) 883-3000, FAX: (415) 883-3303. $79.95. Versions for both IBM and Macintosh computers available. Modem required.*

Using this program, users can log onto the Accu-Weather® on-line weather service using a modem. Accu-Weather Forecaster can then display the hourly weather from thousands of locations around the world, as well as official forecasts and weather warnings, live lightning strikes, satellite pictures and radar images. Off-line, Accu-Weather Forecaster can analyze, map, and graph data using numerous options and search criteria (the hottest places, the windiest, and many others). The program offers discounted rates to the Accu-Weather on-line service. ☐

FOR SALE — 4" apochromatic refractor with 7x50 illuminated finder, equatorial mount, Pier hand controller and all accessories. Asking $4,200. Will deliver within 200 miles. Contact Joseph Nastasi, 35 Brookside Avenue, Greenfield, MA 01301. Phone (413) 774-5769.

ANNOUNCEMENT — The Amateur Astronomers Association of Princeton, Inc. meets the second Tuesday of each month, except July and August, at Princeton University's Payton Hall, Ivy Lane, Princeton, NJ. For more information contact Membership Chairman Greg Mauro at (609) 585-9465.

ANNOUNCEMENT — The Astronomical Society of the Palm Beaches meets the first Wednesday of each month, 7:30 p.m., South Florida Science Museum, 4801 Dreher Trail, West Palm Beach, FL 33405. Two star parties a month. Call (407) 746-8064 for information.

ANNOUNCEMENT — The Small Scope Observers Association is looking for members. If you have a scope 8 inches or smaller, drop us a line and find out more. Send your SASE to the SSOA at 4 Kingfisher Ln., Audubon Park, NJ 08106.

ANNOUNCEMENT — Space Science teachers in North Carolina announce the formation of N.C.-Astro, an organization of astronomy teachers in North Carolina dedicated to improving the teaching of astronomy in the schools of the state. It will strive to provide hands-on ideas to make space education more interesting. It will offer training opportunities during conferences and other meetings and seek to make the public more aware of the importance of astronomy. Anyone interested should write John C. Boling, Jr., Planetarium Teacher, Charlotte-Mecklenburg Schools, Charlotte Nature Museum, 1658 Sterling Road, Charlotte, NC 28209.

ANNOUNCEMENT — The newly formed Astronomical Society of Lenawee County meets at Robinson Planetarium, Peelle Hall, Adrian College, Adrian, MI. Meeting dates work around the planetarium schedule. For information call Jim Whitehouse at (517) 448-8995 or (517) 448-7173, or Joe Noffsinger at (517) 265-5161.

ANNOUNCEMENT — The Comox Valley Astronomy Club was formed in 1990. Based on mid-eastern Vancouver Island in British Columbia, Canada, it serves the area surrounding the towns of Courtenay, Comox, and Cumberland. Amateurs visiting this region are welcome to call David Graham at (604) 339-5738, or Ed Majden at (604) 338-5774. Direct Club correspondence c/o Keith Finnie, 1467 Balmoral Ave., Comox B.C., Canada, V9N 7N9.

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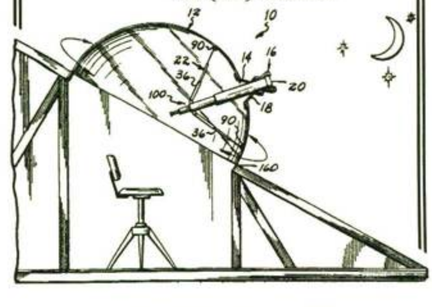

Meade & Celestron
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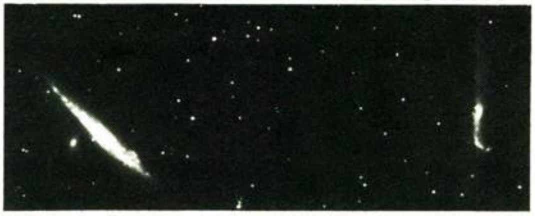
LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO OF THE MONTH



Galaxies NGC 4631 (left) **and NGC 4656/7** (right) **in Canes Venatici.** 50 minute exposure by Martin Germano using 2415 hypered in a LUMICON Hyper-Kit and an 8" f/5 telescope with a LUMICON 2" Newtonian Easy-Guider. Much detail can be seen in 9th magnitude NGC 4631. Look for nearby 12th magnitude NGC 4627. NGC 4656/7 has an interesting hook; look for the hard-to-see faint extension doubling its length.

LUMICON FILTERS — BEST IN THE WORLD!

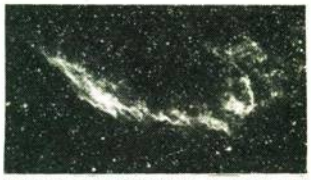
"The LUMICON OIII proved to be our favorite... It gave the greatest contrast gain."

ASTRONOMY February 1991

AMAZING OIII FILTER™

Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90% for both O-III lines at 496nm and 501nm.



"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*

Rich Zepernick, Cresskill, NJ

SEE THE HORSEHEAD!

Horsehead Nebula in Orion. This faint nebula is seen best with a LUMICON H-Beta Filter. Photo by J. Marling using a Deep-Sky Filter.

DEEP-SKY FILTER™

BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. *"Great for BOTH color and black and white photography."*

BEST WIDE-BAND FILTER!

*"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complimentary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for **reflection** nebulae."*

Astronomy, Feb. 1991

	Premium*
0.96" **LUMICON DEEP-SKY Filter** threads into most 0.96" eyepieces	$59.50
1¼" **LUMICON DEEP-SKY Filter** threads into most 1¼" eyepieces	$79.50
48mm **LUMICON DEEP-SKY Filter** (1.7" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	$119.50
2" **LUMICON DEEP-SKY Filter** (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	$119.50
72mm **LUMICON Giant DEEP-SKY Filter** (62, 67, 77mm adapter, $8)	$299.50
1¼" **LUMICON UHC Filter** threads into most 1¼" eyepieces	$99.50
48mm **LUMICON UHC Filter** (1.75" aperture) fits most 2" eyepieces	$199.50
Set of both premium **DEEP-SKY** and **UHC Filters** (Save 11%) ... 1¼" **$159.50**; 48mm	**$279.50**
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. 1¼" **$99.50, 48mm**	**$199.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines ... 1¼" **$99.50,** 48mm	**$199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	$6.95
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece	$16.00
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	$20.00

**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

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Oracle 3" f/7.4 Triplet Apochromat	$750
Genesis 4" f/5 4 element fluorite	$1560
Renaissance 4" f/5.5 refractor	$1560
Complete Equatorial Mount	$795
Motor Drive for above mount	$198
7.4, 10.4, 13, 17, 21, 26mm Plossl 50°	$89
1.8x or 2.5x Tele Vue Barlow Lens	$89
2" Giant Barlow	$219
32mm Plossl, widest true field in 1¼"	$109
55mm 2" Plossl, widest possible field	$219
15mm Wide-Field, 1¼" eyepiece, 65°	$135
19mm Wide-Field, 1¼" eyepiece, 65°	$145
24mm Wide-Field, "superb," 65°	$169
32mm Wide-Field, 2" eyepiece, 65°	$239
40mm Wide-Field, "awesome," 65°	$299
4.8mm Nagler, 82° field	$149
7mm Nagler, 1¼" eyepiece, 82° field	$189
9mm Nagler, 82° field, "the best"	$219
11mm Nagler, 82° field, 1¼" or 2"	$235
13mm Nagler, 82° field, 1¼" or 2"	$249
12mm Nagler, Type II, 82°, 1¼"/2"	$249
16mm Nagler, Type II, 82°, 1¼"/2"	$289
20mm Nagler, Type II, 82°, 2" only	$340
1¼" Paracorr Visual Coma Corrector	$179
2" Paracorr Visual Coma Corrector	$298

NEW! ENHANCED ALUMINUM DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 2.1" enhanced aluminum diagonal mirrors & 1¼" star diagonal.

The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. The extra 5-10% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32"	**$29.95**	1.52"	**$34.50**	1.83"	**$39.50**
2.14"	**$49.50**	2.60"	**$65.00**	3.10"	**$89.50**

ENHANCED ALUMINUM STAR DIAGONAL

*90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼" (1.32" mirror)	**$99.50**
2" (1.83" mirror)(see photo above)	**$159.00**

ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.

LUMICON Adjust. Piggyback Mount $59.50
Specify telescope size: 6", 8", 10", 11", 14", 16"

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	**H-Alpha**	**(MV)**
46, 48, 49mm	**$47.00**	**$39.00**
52, 55, 58, 62mm	**$59.00**	**$49.00**
67, 72, 77mm	**$69.00**	**$59.00**
82mm	**$79.00**	**N/A**

Hypered 2415 film, 36 exp .. **$10.95, $3/$29**

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DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

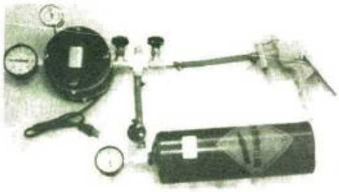
FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$325**



MODEL 600 HYPER-KIT (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$395**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller ... **$595**

Temperature controller for any HYPER-KIT **$65**

Electric Vacuum Pump, Model R-10 **$295**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars.
Specify Camera and Telescope type.

U.S. Patent 4,448,500

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$169.50**
3X Relay Diagonal (see photo)	**$89.50**
Illuminated reticle eyepiece system	**$99.50**

Guider for Hasselblad **$350,** Mamiya 645 **$199**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$225.00**
Adapter for Hasselblad **$198,** Mamiya 645 **$98**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER	**$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20)	**add $99.95**

Adapter for Hasselblad **$229,** Mamiya 645**$129**
Pentax 6X7 **add $129;** Pentax 645 **add $149**

WHAT DO YOU NEED?

1. Illuminated reticle eyepiece **$99.50**
Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, battery pack.

2. Cable release for long exposures .. **$9.95**

3. **LUMICON Quartz Drive Corrector . $219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.

Declination motor (state telescope) .. $99
NEW Deluxe Digital Qtz. Drive Correc. **$298**

NEW SR-G3200

HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). ***No C.O.D.s.***

Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	**$10.95**
SR-G3200, fastest of all, color neg	24	**$13.95**
Kodak Ektar 1000 fast, fine grain	24	**$12.95**
Fuji HG400 fine grain color neg.	12	**$10.95**
3M 1000, fastest slide film	12	**$12.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$6.95**

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IMPROVED LUMICON® SKY VECTOR II™ $589

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- Digital right ascension readout to 1 minute of right ascension (RA)
- Digital decl. readout to 10 arc-min
- 4000 pulse (0.09° accuracy) high resolution encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, date, sidereal time, etc.
- 9V Battery lasts many nights.

Each LUMICON SKY VECTOR™ includes one computer with digital readout, two precision high resolution digital shaft encoders, connecting cables, & mounting hardware (for most popular telescopes). **Specify telescope.**

LUMICON SKY VECTOR™ for Meade 2080, Meade 2120 *(Specify)*	**$399**
For Celestron C-8, C-11 *(Specify)*	**$399**
For Coulter Odyssey 8", 10", 13", 17½"	**$399**
For any alt-azimuth (Dobsonian) scope	**$399**
For Celestron C-14 (rewire dec. motor)	**$498**
SKY VECTOR KIT (for skilled ATM's)	**$369**

Reference catalogues (1000's of objects)

Burnham's *Celestial Handbook*, I, II, III	**$36.85**
Revised New General Catalogue (all NGC and IC, Epoch 1975.0)	**$35.00**
Sky Catalogue 2000.0, Vol. II	**$29.95**

Only the LUMICON SKY VECTOR II has size, **true visual magnitude**, and complete **detailed visual description** for **all** 1500 objects in memory.

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DEC
MODE
STAR
UP
DOWN
Sky Vector II™
COMPUTER SETTING CIRCLES
LUMICON®

LUMICON SKY VECTOR II™ Computer with 1500 object memory, digital readout of coordinates, easy-to-use controls, object size, detailed visual magnitude and visual appearance descriptions.

Please specify telescope type:

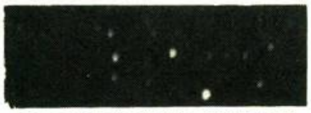
LUMICON SKY VECTOR II™ for Meade 2080, Meade 2120 (*Please specify*)	**$589**
For Celestron C-8, C-11 *(Specify)*	**$589**
For Celestron C-14 (rewire dec. motor)	**$665**
For Coulter Odyssey 8",10",13"17½"	**$589**
For any alt-azimuth (Dobsonian) scope	**$589**
SKY VECTOR II (upgrade, computer only)	**$395**

The **LUMICON SKY VECTOR II™** has all the features of the regular SKY VECTOR, but has 1500 of the best deep-sky objects in memory, selected by noted observer Steve Gottlieb, along with their coordinates, size, true visual magnitude, and complete detailed descriptions. The sophisticated computer programming also will guide you to the object selected by displaying the real-time angular separation. Just move the telescope until the angles displayed become "0" using the "GUIDE" mode.

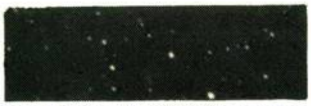
LUMICON SKY VECTOR II FEATURES:

- Includes **size, true visual magnitude & detailed visual appearance description** for all 1500 objects
- All 110 Messier objects
- Brightest 31 alignment stars
- User definable catalogue of 25 objects retained in memory
- 703 galaxies, groups & clusters
- 228 best open star clusters
- 170 best planetary nebulae
- 77 emission & reflection nebulae
- 10 best dark nebulae
- 107 best gobular star clusters
- 205 best colored & multiple stars
- Displays Uranometria 2000.0 chart no.
- ROM upgradable for planets, extended object lists, etc.
- TIMER function, elapsed time & stop watch
- 2 star alignment for alt-azimuth or equatorial telescope systems
- 1 star alignment if polar aligned
- Uses Epoch 2000.0 coordinates
- May align on any of the 1500 objects in memory

COMA CORRECTOR



Coma 1 inch off-axis 17½" f/4.5



Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces. Clear aperture = 1.8".

LUMICON Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER	**$169.50**
2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6x7	**$85.00**
2" Adapter for Hasselblad	**$185.00**
2" Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing	**$26.00**

MEADE® TELESCOPES

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LUMICON ACCESSORIES

NEW PREMIER SERIES TELESCOPES

All Meade Premier Series telescopes **include Smart Drive (SD) permanent periodic error correction**, multi-coated enhanced optics (MCOG), Electronic Command Center (ECC), and **include** advanced LX6 all-electronic drive system. Select f/10 or f/6 optics, and select only the optional features you **need.** The 8" has a 6X30 finderscope and the 10" has an 8X50 finderscope. SD = Smart Drive.

2080 Model 40SD, 8" f/10	**$1650**
2080 Model 46SD, 8" f/6	**$1799**
2120 Model 40SD, 10" f/10	**$2099**
2120 Model 46SD, 10" f/6	**$2298**
Model 2600 16" f/10	**$9950**

Options Enhance Performance

Super Wedge for 10"	**Add $299**
ECC Electronic Command Center	**$275**
#39 Declination motor	**Add $109**
Digital setting circle	**Add $399**
2" Star diagonal	**Add $179**
LUMICON Cassegrain Easy-Guider *(Please specify camera)*	**Add $225**
LUMICON Giant Easy-Guider (for #40) *(Specify camera)*	**Add $395**
LUMICON Giant Easy-Guider (for #46) *(Specify camera)*	**Add $295**

PREMIER 2080 MODEL 50SD $1950

Meade Premier 2080 Model 50SD

MEADE SERIES 4000 EYEPIECES

Super Plossl: 6.4mm, 9.7mm, 12.4mm **$89** 15mm, 20mm, 26mm **$89; 32mm $109**

Super Wide-angle: 13.8mm **$129,** 18mm **$135,** 24.5mm **$149,** 32mm (2") **$219**

Ultra Wide-angle: 4.7mm **$149,** 6.7mm **$179,** 8.8mm **$209,** 14mm **$249**

SCHMIDT-CASSEGRAIN

2045D 4" f/10 w/motor drive	**$695**
2080A Standard 8" f/10 w/tripod	**$999**
2080B Std. w/tripod, MCOG	**$1099**
2080 Model 50SD, 8" f/10	**$1950**
2120 Model 50SD, 10" f/10	**$2399**
2120 Model 50SDH, 10" f/10 w/Super Wedge, Smart Drive	**$2698**
2080 Model 56SD, 8" f/6.3	**$2099**
2120 Model 56SD, 10" f/6.3	**$2595**
2120 Model 56SDH, 10" f/6.3 w/Super Wedge, Smart Drive	**$2894**
Dew shield - essential! 8" **$119;** 10"	**$129**
LUMICON EASY-GUIDER for 2080	**$225**
EASY-GUIDER (f/4-f/10) for 2120	**$395**
CAT command control, 8200 objects	**$999**

SCHMIDT-NEWTONIAN

MTS-SN6, 6" f/5, #788 drive	**$649**
MTS-SN6 w/drive, MCOG	**$698**
MTS-SN8, 8" f/4 w/drive, MCOG	**$795**
#36 LX3 hand cntrl. & #38 dec. motor	**$189**

NEWTONIAN

Model 826C 8" f/6 w/motor, 2" focuser	**$898**
Model DS-10A, 10" f/4.5 with motor, 2" focuser, setting circles	**$995**
Model DS-16AB, 16" f/4.5 w/motor, 2" focuser, Sealmaster ball bearings	**$1975***
8X50mm finderscope w/brackets for DS-10 or DS-16	**$109**

**F.O.B. Costa Mesa, CA*

2" DELUXE BARLOW

1.8x Multiplier Lens

The computer-designed LUMICON 2" Multiplier/Field Flattener multiplies the image scale in photography by 1.8x (f/4.5 becomes f/8). Use it with any LUMICON 2" EASY-GUIDER. Guide-stars also become much sharper to make guiding easier. This lens is optimized for f/4.5, but will work well with any optical system. It may also be used visually as a highly corrected 2" Barlow lens.

LUMICON 1.8x multiplier lens	**$235.00**

NEW! LOW PROFILE HELICAL FOCUSERS

FROM $59.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD.

LUMICON 1¼" Helical Focuser	**$59.50**
LUMICON 2" Helical Focuser 1½" high	**$65.00**
LUMICON Non-rotating Helical Focuser	**$89.50**
2" rack & pinion focuser, only 2" high	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2"/1¼" adapter w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$169.50**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra. The

1¼" 50mm Finderscope **$59.50,** right-angle	**$89.50**
1¼" straight-thru 80mm SUPER-FINDER	**$169**
1¼" right-angle 80mm SUPER-FINDER	**$179.50**
1¼" right-angle version, w/star diagonal	**$209**
25mm Cross-hair 1¼" eyepiece (12X)	**$39**
1¼" Star Diagonal **$39,** Mounting Brackets,	**$37**
1¼" Amici Prism diag. for correct left-right views	**$69.50**

2" ADAPTERS MEADE, CELESTRON TELESCOPES

These adapters convert refractors and Schmidt-Cassegrain telescopes for 2" operation. They allow use of 2" accessories, such as the LUMICON 2" EASY-GUIDER for photography. They also allow use of 2" eyepieces and/or 2" star diagonal for viewing.

2" adapter for C-8, Meade 2080, etc.	**$26.00**
2" adapter for C-80, C-100 refractor	**$39.50**
2" adapter for C-70, C-80F, C-90F, C-100F	**$39.50**
2" Accessory adapter for Comet Catcher, C-6, Meade 312, 321 refractor	**$30.00**
2" LUMICON EASY-GUIDER (state camera)	**$169.50**

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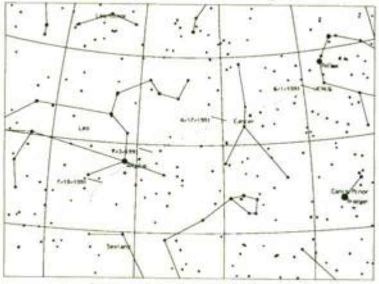

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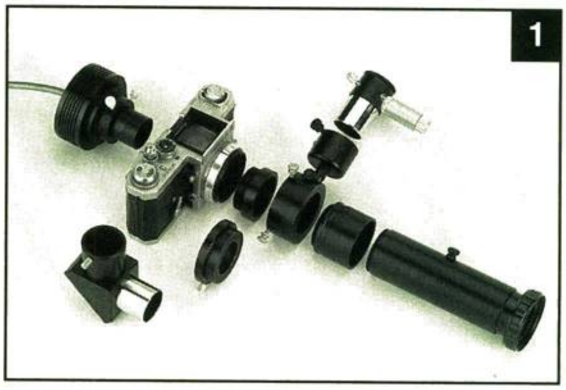
New Astronomy Products



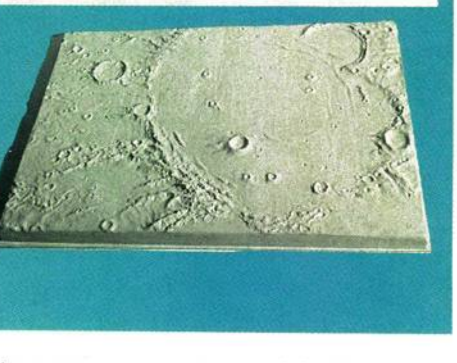
SpectraGuide™

This new guider features a modular system of adapters for use with 35mm cameras, CCD cameras, CCD auto-guiders, and eyepieces. The SpectraGuide is adaptable to refractor, Newtonian, and Schmidt-Cassegrain telescopes. It allows astrophotographers to guide on stars at the edge of the field (as with conventional off-axis guiders) or on stars within the field of view itself. The guider can also be used as a seeing monitor during planetary photography.

*Spectra Astro*Systems, 6631 Wilbur Avenue, Suite 30, Reseda, CA 91335, (818) 343-1352, FAX: (818) 996-7698. Introductory price: $159. Camera T-ring not included.*

2 Educational Models

The Black Forest Observatory has three new models available suitable for use in teaching astronomy. The transparent 3-dimensional Milky Way Galaxy Model locates and names the spiral arms, our solar system, star clusters, and more. The multi-layered acrylic model has an adjustable pivot base and includes an illustrated study guide. The Lunar Landscape Model depicts the Copernicus region of the Moon in raised relief, showing craters, rilles, and plains. Included is an illustrated study guide. The Solar System Orrery is motorized and illuminated (for demonstrations of phases and eclipses) and shows Earth, the Moon, and Venus. It comes with an illustrated instruction book.



Black Forest Observatory, 12815 Porcupine Lane, Colorado Springs, CO 80908, (719) 495-3828. Milky Way Model: $99.95, Lunar Landscape Model: $99.95, Solar System Orrery: $595 (other orreries available starting at $99.95). All items postage paid in continental U.S., Call for Alaska, Hawaii, Canada and foreign shipping quote. Also available: 50-page catalogue (free in U.S., $2 in Canada and foreign).

This department presents new product announcements issued by their manufacturers. The product information is as supplied by the manufacturers or distributors. All prices are suggested retail. Suppliers are invited to send their product announcements to the attention of Alan Dyer.

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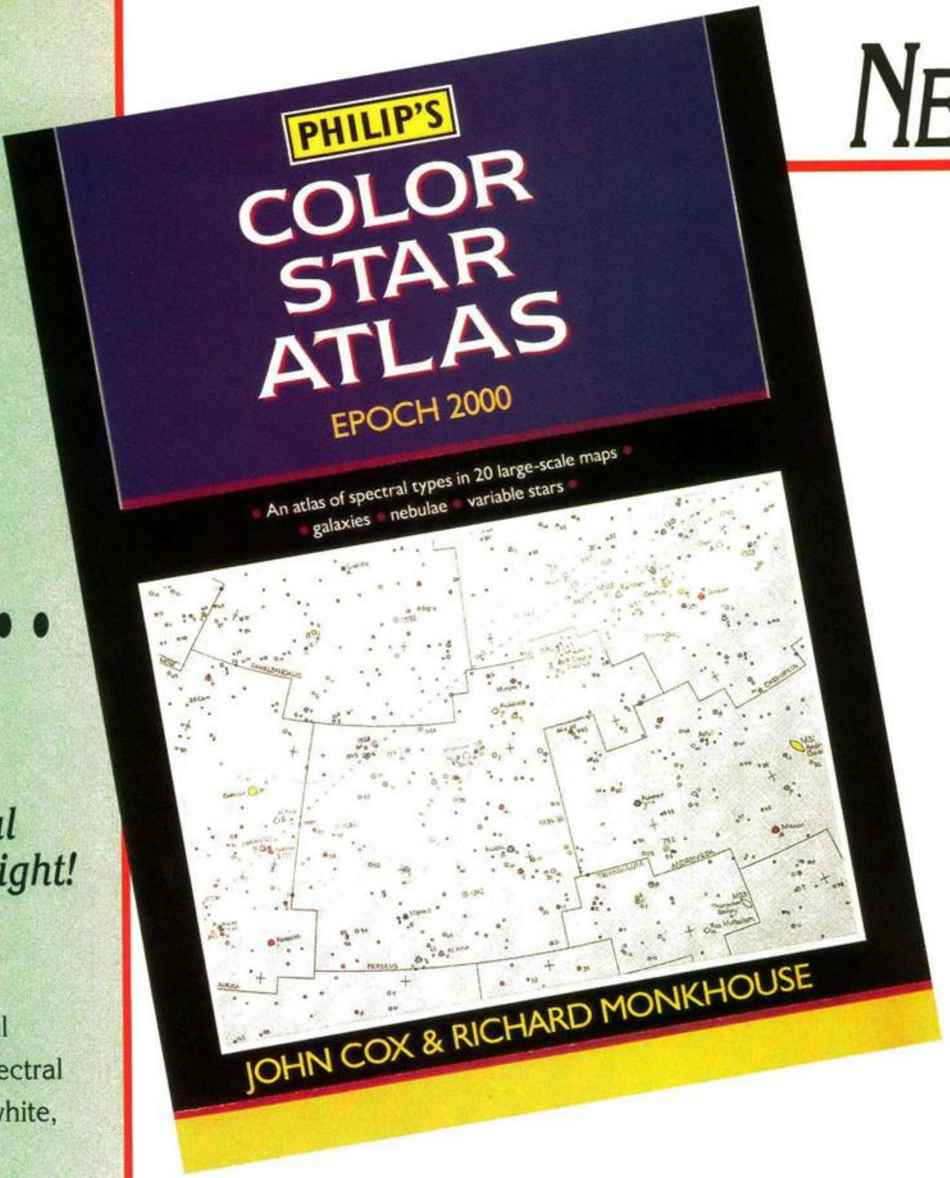
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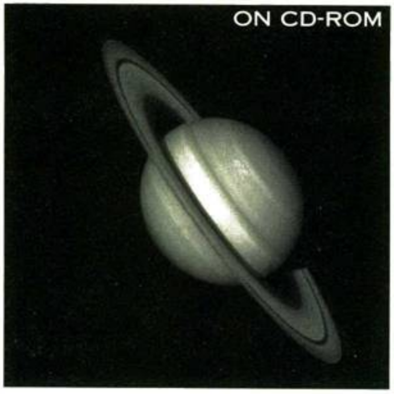

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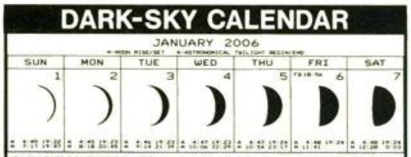

DARK-SKY CALENDAR is a PC program that generates hardcopy monthly calendars on dot-matrix printers. The calendars contain, optionally, the following information for each day:

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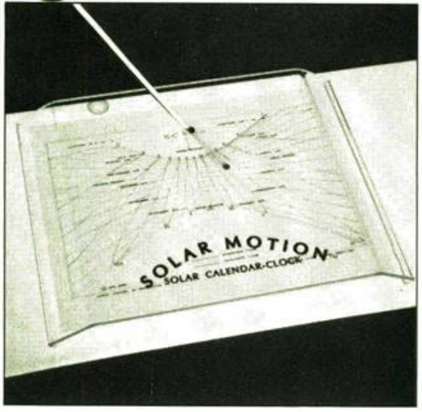

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Versacorp, P.O. Box 7, Sun City, AZ 85372-0007, (602) 972-1878. MicroStar: $69, Adapter/Previewer #1609: $30.

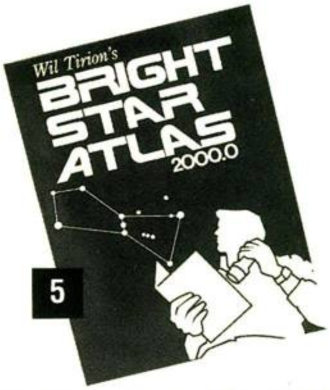
4

The Observer's Calendar
Ventura County Astronomical Society
June 1991 through May 1992

The Observer's Calendar

This calendar features black-and-white astrophotographs and eyepiece sketches produced by amateur astronomers. It covers the June 1991 to May 1992 period and contains daily sunset and moonrise times (calculated for Mt. Pinos in southern California) as well as information on Moon phases and meteor showers.

Ventura County Astronomical Society, P.O. Box 982, Simi Valley, CA 93062. $6 plus $1.50 postage and handling.



5

Laminated *Bright Star Atlas 2000.0*

This popular atlas plots stars down to magnitude 6.5 as well as over 600 deep-sky objects, along with tables of object data and seasonal all-sky charts. The charts have been prepared by the renowned celestial cartographer, Wil Tirion. The special version of the *Bright Star Atlas* available from AstroSystems features plastic laminated pages to withstand dew and outdoor use. The 32-page *Bright Star Atlas* is 9 by 12 inches.

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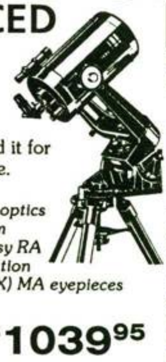

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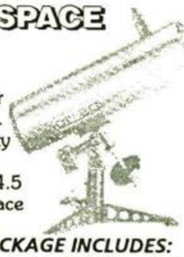

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Meade List Price

Focus Camera Sale Price

MTS-SN6 LX3

as above with LX3 Drive	**729**
#66A Dec Arm	**43**
6x30 Finder	**43**

826C NEWTONIAN

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8 inch 2032mm F/10 Schmidt-Cassegrain optical tube, Super Polaris equatorial mount with slow motion controls, 5x24 finder, 1¼" diagonal 25mm Kellner eyepiece & trunk case.
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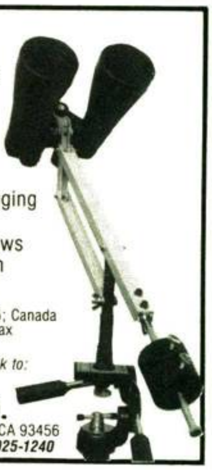

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Meetings & Events

August 2-4
CAFTA Telescope Makers Contest, Village des Terrasses, St-Adolphe d'Howard, Québec. Contact: Société d'Astronomie de Montréal, CP 206, Station St-Michel, Montréal, Québec, Canada H2A 3L9. Phone: (514) 728-4422.

August 7-9
45th Annual Astronomical League National Convention, University of Massachusetts, Amherst, Massachusetts. Hosted by the Amateur Telescope Makers of Boston. Contact: John Reed, 1437 Massachusetts Avenue, Lexington, MA 02173.

August 7-11
Mount Kobau Star Party, near Osoyoos, British Columbia. Contact: Peter Kuzel, 4100 25th Avenue, Vernon, British Columbia, Canada V1T 1P4. Phone: (604) 545-1226.

August 9-10
Astronomical League Northwest Regional Convention, near Ellensburg, Washington. Contact: Thom Jenkins, 3312 South Pittsburgh, Spokane, WA 99203. Phone: (509) 838-1381.

August 9-10
Stellafane, Springfield, Vermont. Contact: Stellafane, 60 Victoria Road, Sudbury, MA 01776.

August 9-11
Boise Astronomical Society Star Party, Bruneau Sand Dunes State Park, Mountain Home, Idaho. Contact: Boise Astronomical Society, Inc., P. O. Box 8386, Boise, ID 83707.

August 9-11
4th Convention of Observers of the Latin-American League of Astronomy, Santa Fe, Argentina. Contact: Jorge R. Coghlan, Secretario del Centro Observadores del Espacio, calle San Jerónimo 4101, 3000 Santa Fe, República Argentina.

August 9-11
Mountain Astronomers' Rendezvous and Star Party, Battlement Mesa, Colorado. Sponsored by the Denver Astronomical Society. Contact: Dave Trott, P. O. Box 10814, Denver, CO 80210. Phone: (303) 871-5172.

August 9-11
Starfest '91, Riverplace Campground, Mount Forest, Ontario. Sponsored by the North York Astronomical Association. Contact: Andreas Gada, 26 Chryessa Avenue, Toronto, Ontario, Canada M6N 4T5. Phone: (416) 761-1798.

August 9-11
21st Annual NFCAAA Summer Seminar, Darling Hill Observatory, Vesper, New York. Sponsored by the Syracuse Astronomical Society, Inc. Contact: Rod McCabe, 706 Campbell Road, Mattydale, NY 13211. Phone: (315) 454-3150.

August 10
Prairie Astronomy Club Star Party, Hyde Observatory, Lincoln, Nebraska. Sponsored by the Prairie Astronomy Club. Contact: Lee Thomas, P. O. Box 80553, Lincoln, NE 68501. Phone: (402) 483-5639.

August 10-11
Dakota Star Watch, Killdeer Mountains, North Dakota. Sponsored by the Dakota Astronomical Society. Contact: John Wetsch, P. O. Box 2539, Bismarck, ND 58502. Phone: (701) 256-3620 (evenings).

August 16-18
5th Annual Alberta Star Party, Waterton Homestead Campground, near Waterton Lakes International Peace Park. Contact: R. A. S. C., Calgary Centre, P. O. Box 2100, Station M, Calgary, Alberta, Canada T2P 2M5. Phone: Rick Ponomar, (403) 381-1332.

August 16-18
Northwoods Starfest, Hobbs Observatory Center, Beaver Creek Reserve, Wisconsin. Sponsored by the Chippewa Falls Astronomical Society. Contact: Bob Elliot, Hobbs Observatory, Route 2, Box 94, Fall Creek, WI 54742. Phone: (715) 877-2787.

August 16-19
2nd Annual Southern Michigan Universal Regional Festival of Stargazers, near Clare, Michigan. Sponsored by the Genesee Astronomical Society. Contact: Richard Walker, 1220 Merkle Street, Ortonville, MI 48462. Phone: (313) 627-9524.

August 23-25
5th Annual Astronomy Rendezvous and Conference, Normal, Illinois. Sponsored by the Twin City Amateur Astronomers. Contact: Sharon Mac Donald, P. O. Box 755, Normal, IL 61761. Phone: (309) 827-4885 (evenings).

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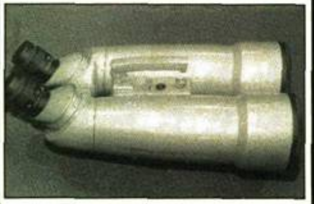

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8"	89.00	8"	76.00
10"	99.00	10"	89.00
11"	109.00	11"	99.00
12.5" to 13.1"	129.00	12.5" to 13.1"	109.00
14"	149.00	14"	129.00
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New Brunswick. Contact: Douglas Pitcairn, 13 Ferguson Road, Dartmouth, Nova Scotia, Canada B3A 4J8.

August 30 - September 2
The Conjunction, Northfield Mountain Environmental Center, Northfield, Massachusetts. Contact: Richard Sanderson, P. O. Box 54, Monson, MA 01057.

September 6-8
Astrofest '91, Camp Shaw-Waw-Nas-See 4-H Camp, Kankakee, Illinois. Sponsored by the Chicago Astronomical Society. Contact: Astrofest, P. O. Box 596, Tinley Park, IL 60477.

September 6-8
Astronomy Weekend, Blackwater Falls State Park, Davis, West Virginia. Sponsored by the West Virginia Division of Parks and Recreation and the Kanawha Valley Astronomical Society. Contact: Pat Northeimer, Box 490, Davis, WV 26260. Phone: (800) 225-5982.

September 6-8
Oregon Star Party and Campout, Steens Mountain, Oregon. Sponsored by the Rose City Astronomers. Contact: Oregon Star Party, Oregon Museum of Science and Industry, 4015 SW Canyon Road, Portland, OR 97221.

September 7, October 5
7th Annual Blue Ridge Parkway Regional Stargaze, Julian Price Park, near Blowing Rock, North Carolina. Contact: Greg Kirby, Route 3, Box 472, Granite Falls, NC 28630. Phone: (704) 396-7656.

September 13-14
5th Annual Observing Party, Cathedral Gorge State Park, Panaca, Nevada. Contact: Jim Mellor, Great Western Hotels, 401 South Casino Center Boulevard, Las Vegas, NV 89101. Phone: (800) 634-6635.

September 13-15
3rd Annual Southern Minnesota Sky Show, near New Ulm, Minnesota. Sponsored by the Minnesota Valley Amateur Astronomers. Contact: Minnesota Valley Amateur Astronomers, Route 4, Box 15A, New Ulm, MN 56073.

October 1-6
Okie-Tex Star Party, Lake Murray State Park, near Ardmore, Oklahoma. Sponsored by the Oklahoma City Astronomy Club. Contact: Oklahoma City Astronomy Club, P. O. Box 21221, Oklahoma City, OK 73156.

October 3-6
Georgia Star Party, Hard Labor Creek Observatory, Atlanta, Georgia. Sponsored by the Astronomical Society of the Atlantic. Contact: Astronomical Society of the Atlantic, c/o Center for High Angular Resolution Astronomy, Georgia State University, Atlanta, GA 30303. Phone: (404) 651-2932 (days).

October 4-5
AstroAssembly, Seagrave Memorial Observatory, North Scituate, Rhode Island. Sponsored by Skyscrapers, Inc. Contact: Conrad Cardano, 68 Colvintown Road, Coventry, RI 02816. Phone: (401) 828-0702 (evenings).

October 4-5
9th Annual Northern Virginia Telescope Meet, C. M. Crockett Park, Calverton, Virginia. Contact: Al Schumann, 6121 Rivanna Drive, Springfield, VA 22150. Phone: (703) 256-8359.

October 4-6
13th Annual Astronomy Jamboree, Southold, New York. Sponsored by the Custer Institute. Contact: Custer Institute, Main Bayview Road, P. O. Box 1204, Southold, NY 11971. Phone: (516) 765-2626.

October 4-6
Connecticut Star Party, Colebrook, Connecticut. Contact: Astronomical Society of New Haven, P. O. Box 3005, New Haven, CT 06515.

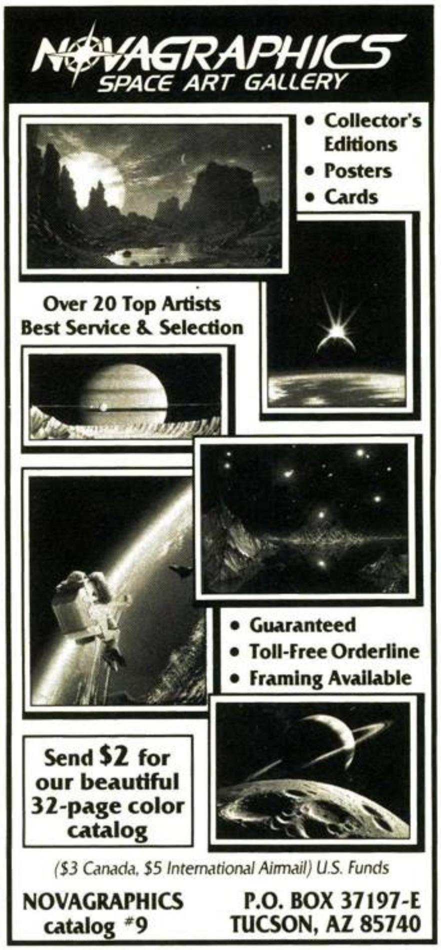
October 4-6
Eastern Iowa Star Party. Contact: Quad Cities Astronomical Society, P. O. Box 3706, Davenport, IA 52806.

October 11-12
Twin Lakes Star Party. Sponsored by the West Kentucky Amateur Astronomers. Contact: Jim Boren, Land between the Lakes, Golden Pond, KY 42211-9001. Phone: (615) 232-7405 (days), (615) 232-6820 (evenings).

October 12
Starfest '91. Contact: Bays Mountain Amateur Astronomers, 853 Bays Mountain Park Road, Kingsport, TN 37663. ☐

Please submit announcements at least four months before the date of the meeting or event.

When you write to organizations listed in Meetings and Events, include a self-addressed, legal-sized envelope with your request for information.



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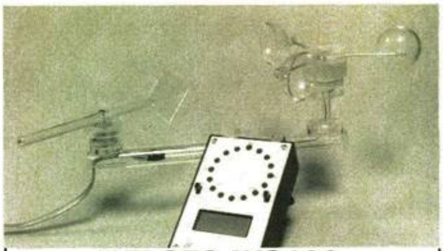

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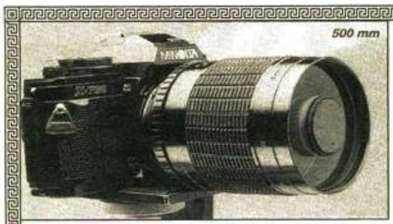

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WANTED — Thirty-one-year-old Brazilian amateur astronomer would like to correspond with others from around the world. Will reply to all letters. Contact Paulo de Tarso de Menezes, Alameda Sao Boaventura 412, Fonseca. Niteroi. RJ. Brasil, CEP 24120.

WANTED — Fourteen-year-old Spanish amateur astronomy enthusiast seeks correspondence with people from over the world. Will respond to all letters. Contact Fernando F. Gutierrez Blanco, c/ Alonso de Ojeda No15-5oC, 33208 Gijon, Asturias, Spain.

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WANTED — Vol.I (Southern Stars) of Papadopodos' *True Visual Magnitude Photographic Star Atlas*; also *USGPO Astronomical Phenomena* '75, '82, '84; *Deep Sky* #2, 11, 17, 19; issues of *Deep Sky Monthly*. Contact Lon at (617) 426-9578.

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Readings and Resources

The Faintest Stars (page 26)

"Do Brown Dwarfs Really Exist," by Deborah Byrd, ASTRONOMY, April 1989. A full-scale exploration of the state of research on brown dwarfs and their contribution to the missing mass.

Neptune's Winds (page 38)

"High Winds of Neptune: a Possible Mechanism" by V. E. Suomi, S. S. Limaye, and D. R. Johnson, *Science,* 251, 929, February 22, 1991. The technical paper behind this article.

Planet CCD (page 54)

"High Resolution Lunar and Planetary Photography," by Rick Dilsizian, ASTRONOMY, January 1988. An explanation of how to take sharp pictures, with nine key factors for success. Although written about astrophotography, the story applies equally well to CCD imaging.

"Tools for the Astrophotographer," Richard Talcott, ASTRONOMY, January 1988. Detailed instructions for using eyepiece projection with cameras; the same techniques apply to CCDs.

Catch a Cosmic Streaker (page 56) and **Night of the Falling Stars** (page 64)

Observe Meteors by David H. Levy and Stephen J. Edberg, (Astronomical League, 1986). An excellent booklet authored by two well-known astronomers who explain how to conduct an organized meteor watch.

Distant Clusters (page 60)

Astronomical Objects for Southern Telescopes by E. J. Hartung, (Cambridge University Press, 1984). Descriptions of thousands of objects including many globulars; a superb handbook.

Saturn (page 72)

The Planet Saturn by A. F. O'D. Alexander (Dover, 1980). A fascinating and detailed history of Earth-based observations from ancient naked-eye views up through the 1960 opposition.

Voyages to Saturn by David Morrison (NASA, 1982). A thrilling look at Saturn as seen by Voyager, written by one of the team members; the sections on the two spacecraft encounters provide a "you-are-there" feel.

CREDITS

Cover: Canada-France-Hawaii Telescope Corporation, T. Gregory, photographer; ***p. 4:*** Greg Furtman, Duluth, MN, March 21, 1991, 10:00 p.m., 28mm lens at f/2.0, Fujichrome 400, 20-second exposure; ***p. 18, bottom left:*** NROA/AUI; ***top right:*** NASA; ***p. 20:*** Tony Hallas; ***p. 22:*** Farhad Yusef-Zadeh; ***p. 24:*** NASA/JPL; ***pp. 26-27:*** Paul DiMare; ***p. 28:*** Thomas L. Hunt***; p. 29, top left:*** Sproul Observatory; ***bottom left:*** Thomas L. Hunt after B. R. Petterson, A. L. Cochran, and E. S. Barker, Astrophysical Journal; ***top right:*** Sproul Observatory; ***bottom right:*** 1960 National Geographic-Palomar Observatory Sky Survey, CIT; ***inset:*** NOAO; ***p. 30, left:*** Palomar Observatory; ***top right:*** NASA; ***right center:*** Thomas L. Hunt; ***bottom right:*** Thomas L. Hunt, after B. Campbell, G. A. H. Walker, and S. Yang; ***p. 32:*** Thomas L. Hunt; ***pp. 34-35:*** William R. Edgar; ***pp. 36-37:*** Thomas L. Hunt; ***pp. 38-39 and 40-41 (top):*** JPL/NASA photo processing courtesy S. S. Limaye; ***p. 42:*** Steve Davis after data supplied by S. S. Limaye, photos JPL/NASA; ***p. 48:*** Dewey Vanderhoff, taken in early August from the Badlands east of Cody, WY; ***pp. 54-55:*** small Jupiter image: Ultima 8 with eyepiece projection to f/22, Lynxx-PC CCD camera, exposure 0.15 seconds, by Richard Berry; large Jupiter images: 16-inch f/5 Newtonian with eyepiece projection to f/26, Lynxx-PC CCD camera, exposure 0.25 seconds, by Donald C. Parker; lunar photos: Ultima 8 with eyepiece projection to f/22, Lynxx-PC CCD camera, exposures between 0.05 and 0.4 seconds; ***p. 56:*** Eric Coulter; ***p. 57:*** Martin Germano; ***p. 58, top:*** Tim Pickering; ***p. 58, bottom:*** Scott Patterson; ***p. 59:*** Gordon Moeller; ***p. 60:*** Jeffrey Corder, 12.5-inch f/4 reflector at 150x; ***p. 61, top:*** Palomar Mountain Observatory; ***p. 62, top:*** Preston Scott Justis, 10-inch f/6 reflector, 103a-O film, 60-minute exposure; ***p. 63, left:*** Jack Metcalfe, 8-inch f/10 SCT, hypered Tech Pan film, 25-minute exposure; ***right:*** Martin C. Germano, 8-inch f/10 SCT, 103a-F film, 35-minute exposure; ***pp. 64 and 65:*** art by Bruce Bond; ***p. 66, top:*** art by Bruce Bond; ***p. 66, bottom:*** Thomas L. Hunt; ***p. 67, top:*** Thomas L. Hunt; ***p. 69:*** Jane B. Lucius; ***p. 70:*** Lowell Observatory, courtesy Bobby Bus; ***pp. 72-73:*** STSI; ***p. 73:*** Donald C. Parker; ***pp. 74-75, from top left:*** Charles and Virginia Capen, Charles Capen, Charles Capen, E. Ken Owen, Thomas Rotkiewicz, Steve Reed; ***p. 77, right:*** Scott Neilsen, 24mm f/2.8 lens, hypersensitized Fujichrome 100 film, 30-second exposure on March 24, 1991, from Superior, WI; ***above right:*** Franklin B. Morgan, 28mm f/2.8 lens, Ektachrome 400 film, on March 24, 1991, from Nichols, SC; ***above:*** Vic Winter, 24mm f/2.8 lens, Ektapress 1600 ISO film, 45-second exposure on March 24, 1991, from Parker, KS; ***p. 78, below right center:*** Ronald E. Royer, 12.5-inch f/6 reflector, Fujichrome 1600D film 1-minute exposure on March 31, 1991; ***bottom left:*** Frank J. Melillo, 8-inch SCT at f/30, Tech Pan film, 1/4-second exposure with 0.6A hydrogen-alpha filter, on March 16, 1991; ***bottom right:*** Lester F. Shalloway, Astro Physics refractor, Panasonic WVD5100 camera, hydrogen-alpha filter, taken at 1991 Winter Star Party; ***top left:*** Bob Crews, taken on February 9, 1991, from Louisville, KY; ***p. 79, top left:*** John Knapp, 31-inch reflector at f/60, Kodachrome 64 film, 1-second exposure on February 11, 1991; ***p. 79:*** Gerald Rhemann, Takahashi E-160 telescope, hypersensitized Fujichrome Super HG 400 film, composite print of two negatives (15 and 20-minute exposures); ***p. 80:*** all images photographed by Jack Newton and processed with Richard Berry's Astro IP software.

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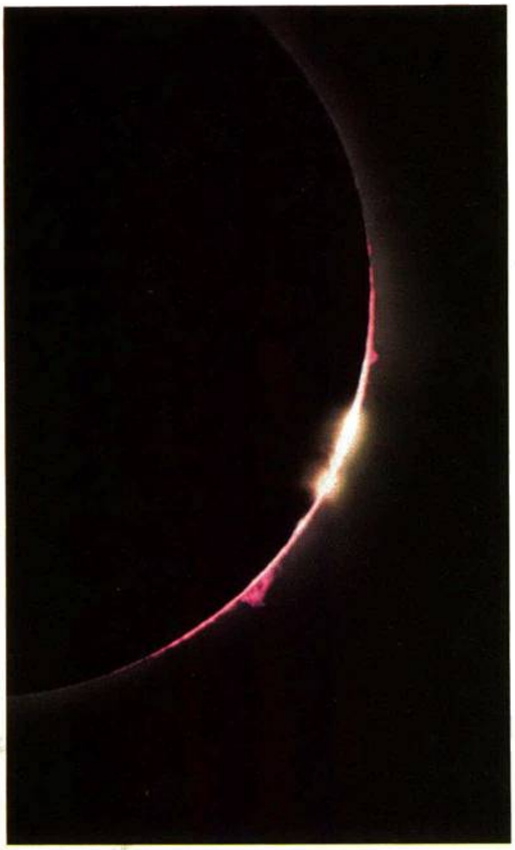

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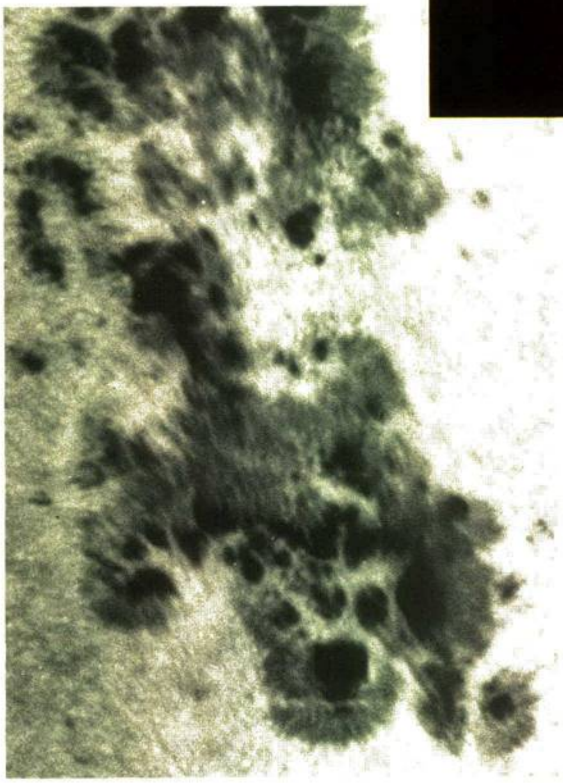

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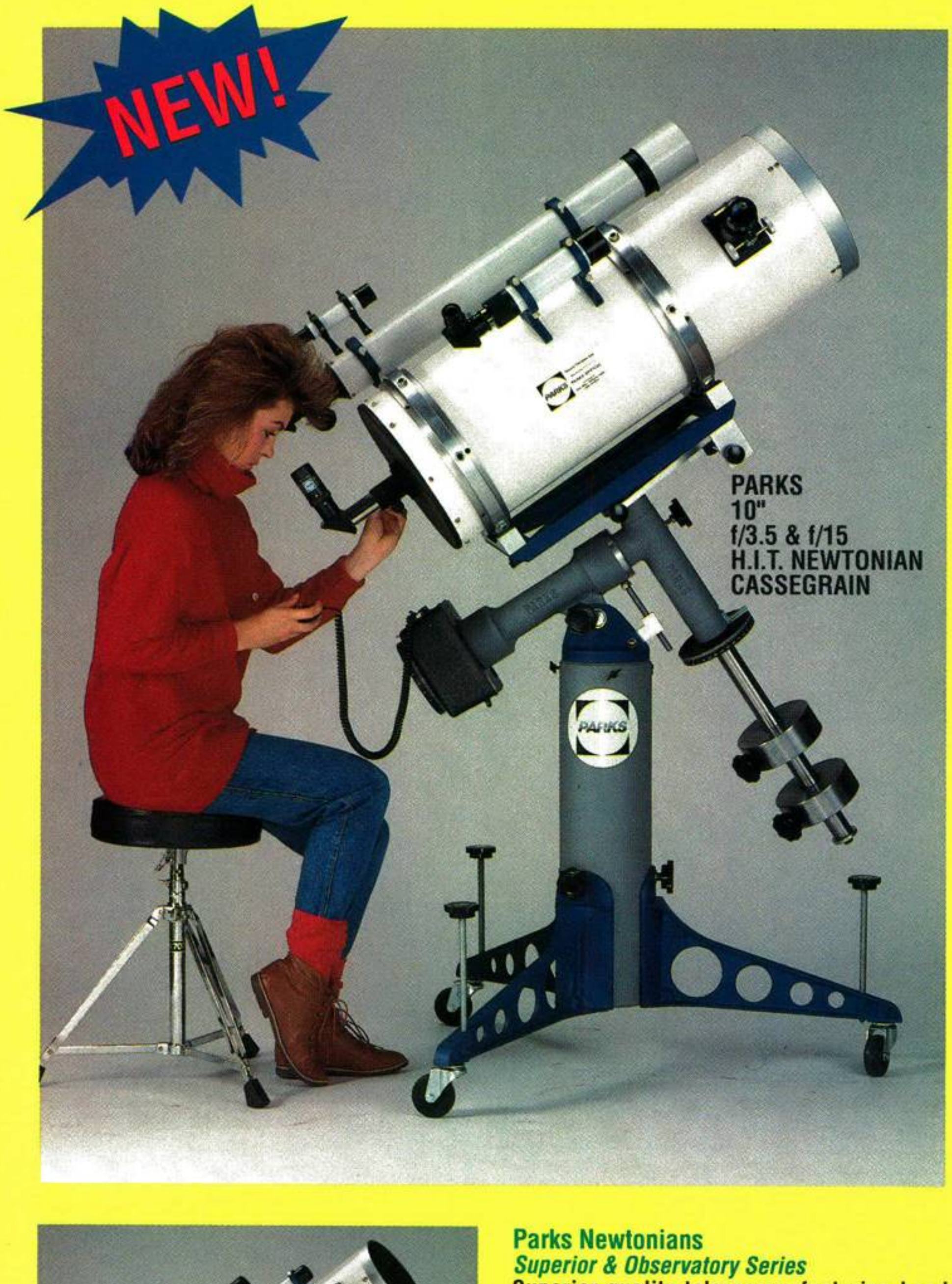

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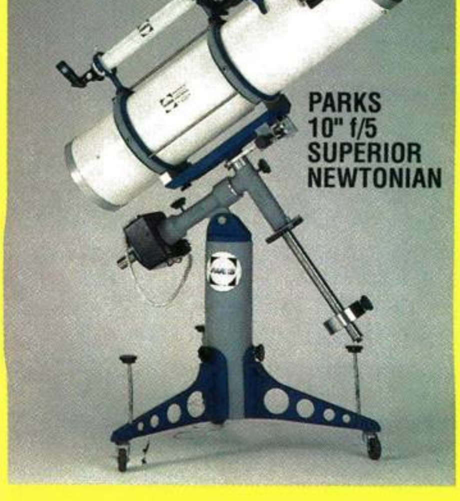
Imagine...the f/3.5 richest field telescope. Imagine observing the Veil Nebula... feasting your eyes on the North American Nebula including Mexico and the Pelican in one field of view. Imagine viewing M81 and 82, or the Lagoon and Trifid or the entire belt of Orion or M31, M32 and NGC 205 all at once.

Now take a few moments and switch your telescope to an f/15 and imagine seeing details of the moon to the size of a city block. See Casini division and Crepe Ring of Saturn, or the Polar Caps and Olympus Mons or Mars. Imagine observing the Great Spot and Festoones extending from the belts of Jupiter.

Parks proudly introduces the state-of-the-art H.I.T. telescope series. Featuring as always the highest quality components, precision crafted and assembled in-house, including hand figured and certified fine annealed low expansion pyrex mirrors, genuine fiberglass tubes, dual axis motors and drive corrector, two Gold Series 1 1/4" 5 element eyepieces and more...the telescope of tomorrow... available today!

SPECIFICATIONS OF THE H.I.T. SERIES:

Tele-scope	*Focal Length at f/3.5*	*Focal Length at f/15*	*Factory Direct for Optical Tube Assembly Only*	*Factory Direct Complete System*
6"	550 MM	2.300 MM	$999	$1,999
8"	700 MM	3,000 MM	$1,299	$2,299
10"	900 MM	3.800 MM	$1,599	$3,399
12 1/2"	1100 MM	4,800 MM	$2,799	$5,299
16"	1400 MM	6,100 MM	$8,900	$15,500



Parks Newtonians

Superior & Observatory Series

Superior quality telescopes featuring hand figured and certified mirrors of fine-annealed, low expansion Pyrex. These optical systems are a product of years of design, engineering, refining, and manufacturing expertise. In a recent test, Sky & Telescope Magazine rated the 10" Parks mirror as the finest of the six evaluated. Quality components are used throughout these telescopes, from the genuine Parks fiberglass tubes to the dual axis motors and drive correctors. Includes two Gold Series 1 1/4" eyepieces & a lifetime guarantee.

Precision Series **- 6" f/6 or f/8- $799.00 F.D., 8" f/6 - $1099 F.D.**

Superior Series **- 1 1/2" shaft mount with clock drive and dual axis drive corrector - 8" f/6 - $2199.00 F.D., 10" f/5 - $2599.00 F.D., 12 1/2" f/5 - $3599.00 F.D.**

Observatory Series **- 12 1/2" f/5 - $7500 F.D., 16" f/5 - $12,000.00 F.D.**

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PARKS DELUXE GIANT BINOCULARS SERIES
11X80
15X80
20X80

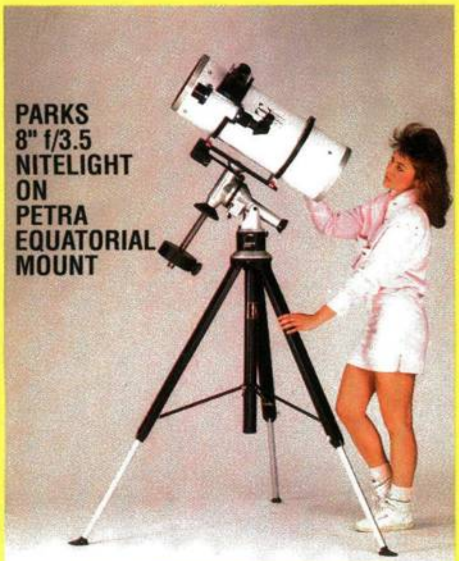
Parks Deluxe 80mm Giant Binoculars

Our 80mm Giant Binoculars are the highest quality available for your money. They feature the leading edge in optical design, with the new BPG2-UV prisms and multi-coated optics. Ideal for view homes, astronomy, or nature study. They feature rubber-armoring, integral lens shades/dew shields, central support bridge, tripod adapter, deluxe case, caps, straps, and lifetime warranty. 11x80 - $399.00 F.D., 15x80 - $429.00 F.D., 20x80 - $459.00 F.D. *Other Quality Parks Binoculars:* 7x35Z - $99.00 F.D., 8x42DCF - $259.00 F.D., 9-17x35 Zoom - $259.00 F.D., 6x36 NO-FOCUS - $199.00 F.D

PARKS JOVIAN-4

Parks Jovian 4

Our Jovian 4 may be the most versatile telescope available. The multi-coated, diffraction-limited optics provide outstanding images visually and photographically. Complete with 25mm 1 1/4" Gold Series eyepiece, 6x30 finder, deluxe case and more. $999.00 F.D., *Other spotting scopes:* Pioneer 15-60x60 Zoom - $299.00 F.D., Widefield 60 - $349.00 F.D., Brass Piratescope - $59.00 F.D.



Parks Nitelight Series

Exceptional fast focal length design (f/3.5). The Nitelight Telescope series are ideal for deep sky observing and astrophotography. These richfield telescopes yield an extra wide field of view. Enjoy nebulae, galaxies, and star clusters like never before. Each mirror is guaranteed to meet or surpass the Rayleigh limit of optical precision. 6" f/3.5 - $1099.00 F.D., 8" f/3.5 - $1299.00 F.D., 10" f/3.5 - $2799.00 F.D., 12 1/2" f/3.5 - $4500.00 F.D., 16" f/3.5 - $13.300 F.D. *Other sizes are also available.*

Parks Refractor Series - Call for information and prices.

PARKS COMPANION
NEW!

New Parks Companion

The newest telescope from Parks. The Companion is a high quality 4 1/2" f/5 Newtonian system. It features the same premium optics and quality construction used on all of our systems. Truly a "richfield" telescope for deep sky observing as well as for lunar and planetary viewing. This new, light weight, compact unit includes: quality Parks Pyrex mirrors, 1 1/4" rack and pinion focuser, 6x30 finderscope, 1 1/4" 25mm multi-coated Kellner eyepiece, tripod adapter block (mounts on any standard photo tripod), and a lifetime warranty. Introductory offer - $399.00 Factory Direct.

Deluxe Vivitar Fluid Head Video Tripod FREE with purchase of Parks Companion.

NEW!
PARKS 25X100 GIANT BINOCULAR

Parks 25 x 100 and 14 x 100 Binocular

Our largest binoculars are multi-coated for maximum light transmission, and utilize BAK-4 prisms. Both the 14x and 25x include a heavy-duty tripod mounting plate, deluxe metal carrying case, caps, straps, and lifetime warranty. 14x100 or 25x100 - $999.00 F.D.

Parks features a complete line of Optical Tube Assemblies, fiberglass tubes and end rings, parabolic primary mirrors, elliptical secondaries, mirror blanks, mirror cells, spiders/elliptical holders, focusers, guidescopes, finderscopes, mounting rings, setting circles, counterweights, eyepieces, visual accessories, ocular adapters, camera adapters and T-rings, Schmidt Cassegrain accessories, clock drive/drive correctors, photographic tripods, complete telescope making components, photo visual and light pollution blocking filters, and accessories.

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The variable brightness LED readout gives you: object coordinates, magnitude, type and when available, common name, constellation and additional description.

Compact, lightweight and easy to install, the AAM can now be ordered in 3 ways: 1) for C8's and Ultima 11 fork mounts, 2) for Super Polaris mounts, and 3) with no hardware (you provide your own). The AAM can be readily attached to just about any homemade mounting, including altazimuth or equatorial.

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STEREO BINOCULAR VIEWER

Seeing is believing and in the case of the Stereo Binocular Viewer this is especially true. Hard to describe in words, Celestron's Stereo Binocular Viewer adds a new dimension (literally) to viewing. With this exciting accessory, you'll swear you are seeing things in 3-D.

With the Stereo Binocular Viewer, all optical surfaces are fully coated with MgFl. It features 45° viewing comfort and interpupillary adjustment (from 53 to 76mm). The head rotates a full 360°. Any 1 1/4" eyepieces can be used and it works with Schmidt-Cassegrains, Maksutovs and refractors.

Markedly improve contrast and definition on lunar, planetary and solar subjects as well as on deep sky objects. More comfortable two eye viewing with less squinting and eyestrain is now a reality!

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Astronomers today demand a top quality eyepiece designed to meet their exacting specifications. An eyepiece capable of complementing the finest quality telescopes. And so Celestron has introduced the Ultima line of eyepieces. Their hybrid design of 4 to 7 elements is engineered to satisfy even the most demanding observer.

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If you are looking for an eyepiece offering high performance, long eye relief, a minimum of aberrations and a wide field, look no further than the Ultima series by Celestron.

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